NIMAL LIFE

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ANIMAL LIFE

A SWARM OF MAY-FLIES

From 'Riverside Natural History'

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ANIMAL LIFE

BY

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WITH 63 ILLUSTRATIONS

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PREFACE

The want of a small work dealing with the adaptations and factors of animal life in a broad and connected manner is my excuse for writing this book. In the simplest form and with the least amount of descriptive structural detail that I can compass, I have attempted to describe the moving spectacle: its abundance and variety, its modes of maintenance and of development, the safeguards of its individual and racial welfare. The evolutionary standpoint is adopted throughout, and in developing the subject I have proceeded by the use of three leading motives that differentiate animals from plants—movement, the acquisition of solid food, and the nervous control of response to changing order. To have included the factors of animal evolution, so far as they are known, would have unduly swollen the volume, and partly on that account, partly also because of such excellent recent accounts as those by J. A. Thomson ('Heredity,' Progressive Sci. Series: Murray) and by R. H. Lock ('Heredity, Variation, and Evolution': Murray), I have omitted consideration of them.

The work is written in the first instance for those who wish to learn or teach such a survey of the animal pageant as can ally itself with observation and experiment; and in the second place for those who wish to organise their knowledge of animal life. References to fuller treatment of many topics are given at the close of the chapters.

I am indebted to Mr. Gordon Hewitt for the loan of the two figures illustrating the house-fly and for revising the proofs; to the Director and staff of the Manchester Museum and to Mr. Greenwood for aid in obtaining the half-tone photographs; and to the publishers and authors specified under the respective illustrations. Miss Emily Dust (Manchester School of Art) has executed the design for the cover. My textual indebtedness to the work of others cannot be clearly indicated, but I may mention that the chapter of insect life-histories owes much to the writings of Fabre, Peckham, Miall, and Wasmann, and that the latter part of the chapter on colour (especially as regards 'effacing gradation') owes much to the writings of the American artist Thayer.

F. W. GAMBLE.

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ANIMAL LIFE

CHAPTER I

THE INTEREST OF ANIMAL LIFE

THE contrast in impressiveness between plant life and animal life is a reflection that every countryside arouses. By the plants we may know the wetness or dryness of a district, its cultivation or wildness, the run of the watercourses, the season of the year, and even the time of day. In civilised countries, where the scenery has been largely determined by man, the national character finds expression, and shows in our own country a generous capacity for half measures, a toleration of opposites, a compromise between formality and freedom, and controls in a characteristic manner the growth of native plants and the cultivation of alien ones.

With the fields and heaths, the woodlands and uplands, in all their varying expressions, generations of countryfolk have had close alliance. Between them and this 'furniture of the earth' there has grown a tie, the strength of which is not realised

until it is broken, and the Devonshire combe or Westmorland fell are images in exile.

To this the animal life of a countryside offers a sharp contrast. Its bulk, in a bird's-eye view, is insignificant, its tenure of the ground is short. It is evasive, and offers no large characters distinctive of the highlands and lowlands, or of the cultivated and open country. It is remote, and for the discovery of its genius a closer attention and a minuter acquaintance than the farmer's or gamekeeper's is requisite. Its individuality is never wholly subdued by the country around it or the breeder who cultivates it. Alone among animals the horse and dog have been trained to a willing understanding of man's wishes.

Mass, stationariness, and pliability—the notes of plant life—are replaced in animals by purposeful evasion, activity, and intractability. The abundance of animals, far from always giving the pleasure wakened by the advent, growth, and even the decay of rich masses of plant life, raises feelings of disgust and alarm as often as those of satisfaction or enjoyment. The evolutions of shoals of fish, the concerted flight of birds, the winding homeward of a herd of cattle, give but an evanescent sense of beauty in comparison with the intimate sense of relief aroused by the sight of a woodland after traversing stretches of bare country. The sense of animal intractability is enhanced when we discover in them no merely passive feature of the scene, but independent and even hostile beings.

A slight acquaintance, however, with the enthralling mysteries of animal behaviour awakens the latent sympathy between animals and ourselves that is one mark of our community of origin. Many of us begin that acquaintance through the sheer pleasure we find in observing and collecting animals, and in watching their habits. To such field-work the most experienced naturalist returns with increasing wonder at the infinite significance of what he sees, at the unexpected number of fresh problems that lie in every shell and feather, in each insignificant worm or insect, in the colours of organisms, in the very games of children, and even in social customs. The shell brings up in his mind the image of an organism with brain, muscles, and glands woven into a fabric that has no caprice in its most delicate folds, whose care for itself and its offspring implies ceaseless evasion of fish and shrimp and cunning defence against the destructive power of the waves. The feather, with its perfect system of hooks and eyes, by which its plumes form a firm, airtight membrane for flight or for retaining warmth, is another casual object of beauty and significance. The meaning of its colours, its position on the bird's body, its replacement at the moulting time, are but the first of many problems that a feather suggests. The worm remains no longer a degraded creature or one remote from human interest, for the study of worms has suggested the most effective of modern treatments of that most terrible of skin diseases—lupus. It was by the behaviour of

earthworms under the influence of special rays of light that the treatment known by Finsen's name owes its origin.

Finsen noticed that when the prismatic colours of sunlight are successively cast on the worm, the blue and violet rays—and they alone—cause irritation and distress. Accordingly, he began a systematic work on the different effects which coloured light exerted in virtue of its properties on healthy and diseased skin, and the beneficial effects of his discovery are now restoring to health and activity every year hundreds who but for this work on worms would have received no effective assistance. But the earthworm is far more than the *corpus vile* of a successful experiment. It is the unseen agriculturist, bringing the subsoil to the surface for light, air, and rain to vivify and replenish. It is the preserver of ancient monuments, protecting them by an encasement of earth from destruction. More significant still, it is one of a tribe whose ancestors have had a great share in the origin of higher forms of life. The links that bind together the crab and lobster—the Crustacea—the insects, and probably even the vertebrate animals, find their common starting-point in the lowly worm, and as we trace back some natural characteristics of our race to an obscure tribe, such as the Frisian, so does the naturalist trace the hidden peculiarities of the structure of the higher animals to the worm, in which those features are more manifest.

Perhaps the most unexpected results of this historic

and genealogical treatment of Nature have been obtained in the games and customs of mankind. What seems more irresponsible than the behaviour of village children who come every evening to a chosen spot and sing and dance? What further meaning can there be in a harvest supper than a thanksgiving for the ingathering of the crop? Yet the words children sing are often charms said before hunting, over water, or at burial, altered almost beyond recognition from the invocation they represent; and the harvest supper, like our birthdays, Christmas Day, and Midsummer Day, links us with pagan man and the worship of the spirit of vegetation.

As there is no known limit to the significance of animal life and behaviour, so we cannot set bounds to the influence of such knowledge on human life.

Whether we consider its effect on our physical, æsthetic, or scientific faculties, we find that a biological education offers an unrivalled field for observation, to which even children turn with an enthusiasm that needs rather restraining than encouraging.

The magic of life in the hidden ways and half-lights that field-observation discovers, stimulates the sensitive and artistic nature to a new sense of wonder. 'The cry of the curlew is one of the three oldest cries of the world.' [1] The elevating effect of the quest of significance, the practical advances that biological research has made and will make in hygienic and agricultural practice, and a more vivid and intelligent

[1] W. B. Yeats.

sense of our community with living nature, are but some of the influences which the study of animal life confers, and will confer beyond any limits we can at present assign.

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CHAPTER II

THE FULNESS OF THE EARTH

THE greatness of living nature lies in its bounty. To the earlier races of mankind this fulness was brought home by the increase of herds and crops, on which their sustenance depended. 'The cattle upon a thousand hills,' 'The valleys also are covered over with corn'—such were the images that conveyed a joyful sense of the full measure of earth's ungrudgingness. From time immemorial, men have acknowledged their dependence on the fertility of nature by appeals to the spirit of vegetation and by charms against malevolent influences. They realised that success in raising foodstuffs and stocks was only possible by opposing the inroads of weeds and beasts of prey. In the abundance of locusts or lions, of weeds or rust, they saw that the fertility of nature was not directed to the good of man only, and also that through the powers of increase which man shares with animals and plants, arises the keenest of all forms of the struggle for existence. Small wonder the early shepherds celebrated successful harvests or increasing herds.

In later times the wonderful diversity and richness of human and animal life became more widely

recognised. The voyages of the Spaniards and Portuguese, of Cook and his successors, revealed the presence of new races of men in many parts of the globe, while only sixteen years ago Stanley discovered a race of pigmies living in the equatorial forests of Africa. Strange stories of manlike apes were brought from Africa and Asia by travellers who described the ferocity and strength of these gorillas and orang-utans. From American settlers came news of the herds of bison that roamed the prairies, travelling from grazing-ground to salt-lick with the same mysterious and unfaltering precision that the camel of Eastern deserts shows in adopting its line of march. Hunters told of the life of the jungle, with its strange midday silence, that each night and morning wakens into a roar of activity ; and sailors brought back from their voyages parrots and monkeys, pearl-shells and coral, mementos of their travels that added emphasis to the recital of their beach-combing adventures and opened vistas of new worlds to their enthralled hearers. And still there return, from the exploration of lands untrodden before by white men, travellers laden with tidings of new animals. The tale of earth's fulness is not yet complete.

Life in water as well as on land has become known to us in similar ways.

The craft of fishing and the need for water-transport brought the abundance of aquatic life early to the notice of men. In pursuit of their livelihood, fishermen could not fail to notice the birds of the marshes, the

frogs of the swamp, the watering-places of deer, the footprints and bruised reeds where wild pigs had wallowed or cattle had come down to drink. To the coast fishers the flocking of gulls indicated the shoals of fry; and a school of dolphins or porpoises in pursuit of mackerel or bigger game pointed out to them those waves of migration that set in towards the shore, and after an interval as mysteriously recoil to other coasts or into deep water, carrying their pursuers along in the chase.

Floating helplessly off the shore or cast up on the beach even of our own coasts, there have been found from time to time strange creatures that justify the widespread feeling of the unplumbed possibilities of the ocean: ribbon-like fish twenty feet long, huge turtles with leathery skins, grotesque sun-fish, and eagle-rays of gigantic size. When searching for bait among rocks encrusted with animals, men found, even as we find to-day, cuttlefish and conger-eels sheltering in their crevices, strange worms of unusual size and agility that broke into pieces which crept and wriggled along as though the severance had endowed them with fresh life.

With the coming of spring the longshoreman would notice a change in the beach. Over the sands, under the stones, and round the weeds he would find pears, grapes, purses, and strings of jelly hardly firmer than the stinging medusæ or the fleshy polyps and anemones that meet him the year round. He knows that, like the foam, the medusæ soon dry to a film, and is

therefore led to conclude that the sea-jellies are sprung from the foam, and that even the more substantial creatures of the summer are also of halcyon birth.

The very names of the animal jetsam that we pick up on the beach keep this Greek idea—that the sea is the mother of life—fresh in our minds: the common fleshy pink polyp, our 'dead men's fingers,' is named Alcyonium ; the jelly-like, shapeless, brownish polyp thrown up in ribands is Alcyonidium ; the kingfisher that flies arrowy as foam before the wind is Halcyon ; the days most children recall with greatest glee—the days spent on the sands—are the halcyon ones.

That the sea-jellies are the egg-cases of fish, worms, snails, and cuttlefish (fig. 1) is a discovery of recent times. And yet so unwilling is the mind of seamen to accept such a reasonable origin, that these Greek traditions of the rise of creatures from inanimate nature, and of the transformation of the egg-cases of worms into young fish, survive as lustily as ever the spread of modern education.

This acquaintance with the larger forms of animal life, begun by the shepherd and hunter, the fisherman and explorer, has been continued by naturalists, with the result that an altogether fresh idea of the fulness of the earth has been obtained. By the use of magnifying-glasses it was found that creatures far smaller than insects abounded in sea and fresh water, even as the midges in the air or ants and greenfly on the ground.

The furry coating of weeds, the scum round farm-

yards and decaying plants, the very dust of the air and the depths of the sea, contain an abundance of

FIG. 1.—Group of Egg-capsules of a Squid (*Loligo*), one of the Cuttlefish. The dark spots indicate the eggs. Natural size.—(*From a specimen in the Manchester Museum.*)

animal life. In the far north and south, as explorers sought the Poles, they found birds and seals in plenty;

whilst, under the ice, so numerous were the shrimps that a seal's head let down amongst them at night was a clean skull next morning. As ships sailed through the ice-packs the patches of discoloured water showed the whales' food—myriads of small organisms drifting south with the cold Labrador current. Voyagers to the southward saw the water aflame with phosphorescent light, each glowing point a living animal. From the surface downwards, for some twelve hundred feet, tow-nets showed the sea teeming with animals, and, at greater depths, a peculiar but less abundant deep-sea life flourishing amid intense cold and darkness.

The bountifulness of nature lies on every hand if we have but the second sight to discover it. The little brown scales on an orange, for instance, are sedentary female insects, other kinds of which attack the apple and hawthorn, the larch and birch. These the tomtits know better than we, and take for their winter food. Greenfly, unseen in winter, becomes a plague in summer, covering our flowers and shrubs, crops and trees; blown from overhanging boughs on to the corn beneath; eating the roots at one stage, the leaf at another; and finally, some close, warm day, drifting in a winged swarm over the countryside. The hum of life, now faint, now clear, is the sign of summer's abundance. But even winter is not lifeless to those who know how to seek. Where leaves have drifted out of the wind into shelter, under the warm covering of moss, among clods of hedge-banks, in the earth under

FIG. 2.—A shoal of Jelly-fish, about one of which (*Rhizostoma*) a group of young Horse-mackerel are finding shelter. A *Chrysaora* in the foreground, *Aurelia* in the background.—(*After Haeckel and Kuckuck, by permission of J. B. Baillière et Fils.*)

stones, in the mud under water, animals and their eggs abound.

When brought into a warm room a bag of leaves and moss, searched on a white surface, breaks out into unexpected life—a solitary bumble-bee stirs, a newt stretches its body, beetles uncurl their limbs and creep about, caterpillars wake, spiders lie entranced, ants that lay sleeping wake in agitation.

Clods broken up under warm water show as clear evidence of the hidden life within them. Dried mud from distant countries will then develop the eggs of shrimps, weeds, and Infusoria from those lands. In this manner cultures of many kinds may be made.

Boundless as is the profusion of animal life, we know that in the near and remote past its abundance was no less. If the Pyramids of Egypt are monuments of human endurance and skill, the animalcules that compose those buildings have left therein a record not less impressive than the tale of slaves worn out in hodman's service.

In the fells of northern England, in the cliffs and downs of the south, the very rock represents the labour of innumerable hosts of animals that have secreted salts from the ocean and deposited them as coral and shell, sea-lily and sea-mat. Limestone and chalk, with all the buildings and walls made from them, are due—and exclusively due—to living organisms, though trace of their presence may have

disappeared on account of the heat and pressure to which the rock has been subjected.

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CHAPTER III

THE ORGANISATION OF ANIMAL LIFE

THE thought of this abounding animal life brings to mind its multitudinous variety; the individuality of man; the personal distinctness of animals, more evident as we grow more familiar with them; the separation of creatures into kinds or species, marked off one from another by intangible and yet seemingly impassable boundaries; the mighty gamut of the scale of being. In variety, as in number, animal life witnesses to ungrudgingness.

Yet this prolific variety is limited by orderly control. Life everywhere displays organisation. In plan, as in execution, this is true of the relationships and also of the bodies of animals. That original 'we' is no unattached, new thing. We are body and soul of our ancestors. In features, behaviour, and constitution we acknowledge their gifts. Nor does our indebtedness stop there. Brought face to face with our poor relations, the apes and monkeys, we see, but do not acknowledge, remoter ties. The plan and construction of our bodies and of theirs is the same, but we are unwilling to accept this because we are possessed by the idea that they have too little

intelligence to be likened to man, and we forget that it is their having intelligence at all which justifies us in regarding them as fundamentally related to him.

From the apes we may pass to all the remaining animals that suckle their young and are coated with hair. These—the Mammalia—are interconnected by ties of structural agreement which investigation discovers in almost every bone and tissue, and even in the very blood itself. As proof of relationship, blood has lately vindicated its claim to pre-eminence. There is a test to which the blood of each mammal responds, and the nature of this response given by one species, compared with that of any other species, shows the close or remote connection between the two animals.

Ranking below the hairy animals, those of feather and scale flock together. Unlike as birds and reptiles seem, the connection between them is closer than that between either and any known third group of animals. It is seen in the construction of the bony framework, of the muscles and tendons, in the blood and in the eye, in the brain and in the egg. All the differences which exalt the bird—warmth and sustained activity, voice and exuberance—are the outcome of reptilian characters.

After the reptiles come the sluggish Amphibia, creatures of the swamps—the newts, salamanders, frogs, and toads. Breathing both through the skin and by the lungs, these animals are only partially emancipated from aquatic life. In this and other respects they stand halfway between reptiles and fish.

FIG. 3.—*Lacerta vivipara*, the Common Brown Lizard.—(*From a specimen in the Manchester Museum.*)

FIG. 4.—The Common Slow-worm, a footless Lizard (*Anguis fragilis*). The thin, small specimens are ten days old; the larger one above is three weeks old; the largest, below, is five weeks old.—(*From specimens in the Manchester Museum.*)

Fish alone have true median fins, and usually also the two pairs of fins that correspond to our arms and legs. The gills, reduced in ourselves to the framework of the larynx and parts of the middle ear, are seen in their full development as tufts with elaborate bars for their support, and with muscles for conducting gulps of water in at the mouth, over the tufts, and out through the gill-slits. Movements of the body are carried out mainly by the muscles of the back and tail, which are flattened either laterally or from above downwards; and to steady the unstable fish and increase its propelling force the surface of its trunk and tail is expanded into median fins. The paired fins, so essential to higher animals for locomotion, are mere steering-organs for fish, and in the lowest fish of all—the lamprey and its allies—are entirely dispensed with.

Between these four divisions: mammals, reptiles and birds, amphibia, and fish, there is a deep-seated fundamental likeness. Differing as they do in the execution of the design, these groups agree in the plan of their bodily structure, and for this reason they can be classed together as vertebrate animals.

In a similar way, the bewildering variety of invertebrate life can be reduced to groups subordinate to these six larger groups: the Protozoa (simplest and most primitive of animals); the Cœlenterates (zoophytes, anemones and corals); the Molluscs; the Arthropods (insects, centipedes, and Crustacea); the Echinoderms (sea-urchins, sea-lilies and starfish); the

FIG. 5.—Group of Newts (*Triton cristatus*), showing the differences between the Crested Male (right hand and top figures) and the smoother Females (left and central figures). ¾ natural size.—(*From specimens in the Manchester Museum.*)

earth and water worms. Through each of these six divisions there runs an air or theme, of which the animals themselves are the innumerable variations or fugal developments.

Amongst the members of each of these principal groups we find one dominant tendency—to possess the earth. Having realised this, they are in turn replaced by others, so that if by the aid of fossils we look at the history of vertebrate life, we find as we recede further and further from the present that in the order of their supremacy animal groups suffer eclipse. First, all traces of man disappear; then at a still greater distance of time the mammals and birds vanish; another stage further back and the reptiles, hitherto so abundant, are no longer found; whilst in a still more ancient time the newts die away, leaving only fish of a few kinds analogous to our sharks and to the garpike of American lakes. At the most remote epoch of which we have any recognisable animal records, no vertebrates are found amongst them.

From invertebrate beginnings we find fish developing into a multitude of forms, peopling the rivers and lakes by immigration from the sea, to which many return, as to their true home, when their life is ending. From the ancient armoured types to lamprey and shark and bony fish, each division becomes more and more complex and highly organised as its dominion increases and its circumstances improve, and remains simple if its life remains uniform.

In the rivers and swamps armoured newts arose and wandered over the damp coal-forests and lake shores as the alligators do to-day, whilst their descendants, the multitudinous frogs and toads, have still only partially emancipated themselves from aquatic life in order to gain that life on land which favours the height of animal development and gives it new impetus and variety.

The history of reptiles is a chronicle of more stirring events. From a remote epoch, and dim as all such origins are, the first reptiles appear, almost indistinguishable from the armoured newts, their contemporaries. They were the colonists of those days, and, with an adaptive power of meeting new circumstances that the newts had never shown, became masters not only of the swamps but of the sea and land. Some grew to the size and acquired the habits and shape of whales. On land they stood upright, high as houses, and with their hands reached to the greener boughs of lofty trees. That most difficult of all such conquests, the dominion of the air, they effected, and in their own way solved the problem of flight. Success such as this opened up still other paths of life, for which further variety of form was needed. Small as well as great could find places in these newly acquired kingdoms. The development of vertebrate life seemed a lasting work, finished in its main outlines.

Yet in this heyday of reptilian life another group,

destined for supremacy on land and sea, was beginning its career. From small rat-like creatures the earliest mammals soon rose to manifestations of size, strength, and pliability which only reptiles had hitherto shown; and as the mediæval periods of the earth's history were ages of reptiles, so the prehistoric and historic periods form the ages of mammals. Wave after wave of life has risen from the inexhaustible depths of nature, towered to a great height, and has then fallen; yet undelayed the onward movement continues. In variety of life the period of mammals is the richest of all. As heir of the ages, it has the offshoots of vertebrates and invertebrates whose first exuberance is past. Holding the promise of the future, it contains the seed of the coming dominant races: and to those at their prime, those which have overcome and taken possession, the earth yields her heaped measure of variety and abundance.

It is therefore clear that an animal does not enter upon its life unrelated in structure or habits either with those about it or unadapted to the station in which its lot is cast. Its body displays to the practised eye unmistakable marks of its place in the organised system of life; and its structure bears witness to the precise place or specific niche which it occupies in that system. If a member of a dominant race, it may soon step into a position which less specialised animals of more lowly birth never attain. The landowner's son has the start over the labourer's.

The problems by which animals and ourselves are confronted can be resolved into three :—

1. The maintenance of self.
2. The development of self.
3. The welfare of the race.

To the maintenance of self a station in life is necessary, power to acquire food and to repel enemies, ability to build up the food into that frame which is the outcome of past history bequeathed to its possessor by its parents. In this activity an animal is guided by a faculty for orderly response that shapes its behaviour. Through these responses it gains a sense of the world around, and the habits so formed are as original, and yet as much the outcome of latent inherited capacity, as the body which they direct.

But an animal is not born fully formed or completely endued with all the psychic experience that it needs. Not merely to maintain itself, but to develop, is its task, to which every impulse awakened by the outer world of light, water, and air, or the inner stimulus of hunger, activity, and desire, impels it. Impressions keener than any subsequent ones teach a newborn creature the unexpectedness of events. If a marine animal, it learns the difficulties of balance, the rise and fall of the tide, the brightness of day and darkness of night, the qualities of surface and of deep water. If a land animal, it encounters the varying heat and cold of air and earth, discovers the weight of its body, and the difficulty of sustaining and propelling it. If sufficient food is obtained, it grows

both in size and complexity; and so imperious is this demand for development that, to satisfy it and give material for elaboration, the very tissues of an animal may be sacrificed, and remoulded by a process to which it passively submits.

Fresh impulses fit to guide this altered self are developed in it, and are evoked perfectly at the first trial, or after a few failures. If this experience leads to a wider range of activity, the animal rises in the scale of being; if it leads to a narrow range or fixed habit, development becomes retrograde. As the responses govern the behaviour of an animal and give it character, so this advance or retreat of the individual is governed by the supreme factor of racial welfare.

The welfare of the race is the end to which individual well-being is subjected and often sacrificed. It is rather a motive that possesses animals than is possessed by them. It determines the formation and policy of hives, the building of nests, the colours of eggs, the care of the young. It transmutes inactive fish and beasts into vigilant and ferocious defenders of their young. It is the highest motive that governs individual and national conduct, and has produced that heritage of freedom and social stability which we enjoy as we inherit the physical and psychical organisation that constitutes our being.

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CHAPTER IV

MOVEMENT

MOVEMENT, more than any other feature of animals, brings to us the meaning and working of their life. Activity is the sign of life, and as its manifestations exhibit control and adaptation, so does the organism that displays them rise in the scale of being. Beginning with the animalcules and jelly-fish, which have at best but feeble swimming movements, we pass to the creeping things that cling to the ground or dart spasmodically from one resting-place to another, and then to the Crustacea and insects, in which the problems of walking on land and of flight through air are first solved.

The flight of insects is not only the most perfect movement known, but it has also raised these animals to the highest place amongst invertebrates. Their flight may be only temporary, but it is upon the superiority so gained that their life exhibits organisation, and even civilisation of the most complex kind.

The movements of vertebrates in water, on land, and through the air, bring home the same conclusion. Fish born and bred in the water are the lowest members of the group ; and the most specialised

families of fish are those in which, as in mackerel or tunny, the art of swimming is most masterly. Amphibia, that lie motionless for long intervals, have remained stationary in the scale of being, whilst reptiles, though capable of the most rapid running, gliding, and striking movements, are, owing to their frequent lethargy, only mediocre vertebrates, surpassed by both mammals and birds, which in virtue of their more sustained activity have attained the premier position.

There is an æsthetic side to the movements of animals that makes us never tire of the spectacle. The ease with which fish and porpoises advance, turn, and press onwards under a sudden impulse, the sense of restrained strength in the taut muscles of a horse or dog, the freedom and masterliness of flight, the graceful form and manifold rich colouring of birds, lend inexhaustible attraction to the study of motion.

The energy of many animals has something of that enduring and periodically varying quality that belongs to river, wind, and sea. Gulls and albatross follow in the wake of vessels for days, and even weeks, with no sign of weariness, sleeping on the water and only stooping to feed. Fish when not in active movement are untiringly adjusting their balance by small muscular contractions. The beating of the heart, on which all other motion depends, endures night and day, and exhibits a rhythm of diurnal quickening and nocturnal slackening which is symbolic of the flow and ebb that rules living and inanimate nature.

The full epiphany of animal movement is seen in the behaviour of migratory flocks. Migration is essentially an oscillation between breeding-ground and feeding-ground. On the first, nests are made and the young reared and educated; on the second, parents and young have no connection. Each lives to himself and the young grow to maturity.

When the nesting season approaches, an impulse, the most powerful and selective in animal life, draws mate to mate and fills unmated migrants with a longing that cannot be satisfied save in a far river, or sea, or country. Mated couples of birds desire the particular cottage eaves or hollow on a moorland that has served them for nesting so long; the pride of the hook-jawed salmon is only satisfied by the river that he left last year for the sea; while the upstream eels that leap with the first autumn spate, congregate in a thick mass on their start for the sea.

In this rush for the breeding-ground a new appearance envisages the migrants, a new strength possesses them; instincts that lay dormant rise up and direct their way, notes unknown save at this time of dangerous travel are heard.

Then all our migrant birds make for the north. The ducks, geese and waders, the fieldfares and redwings, leave us for the Arctic, for Norway and Siberia. From the south come our swallows, warblers, cuckoos. Wave after wave, starting from Algiers, Tunis, Syria, and even the coasts of the far south, send northward their migrants seeking homes. Rarely do they

rest. In one or at most two flights at night is the journey done. Flying low down over the earth and sea if the night be dark, filling the air with their strange migratory cries, they are carried on through all weathers by an instinct that only errs, moth-like, at light in the gloom ; or if the night be clear, high up, often out of sight, where the cold and lightness of the air would numb and overcome us, they take their way and arrive at the haven where they would be.

But even before summer is over the return movement southward begins. First the unmated birds slip away. Then the birds of the year, perhaps under pressure of circumstances, yield to this new migratory impulse, that leads them to forswear the county and country of their birth and to find their way unaided across water to lands not their own. Lastly come the parents, flock by flock, not in the solid phalanx that they presented as a northward-going host, but silently and in detachments, with the dress of spring worn out by the summer's housekeeping or replaced by a new but duller garb. More leisurely now and by less direct routes they make their way to the Mediterranean, to the Ægean, and to southward-lying lands.

Modes of Animal Movement.—If we imagine a man in a boat provided with oars and boathook we can think of four different ways in which he may effect movement: by punting with one of the oars against the bottom of the water ; by hauling against brushwood or other obstacles on the banks ; by sculling from the stern with a single oar, or by rowing with a pair

of oars. The effort necessary to move the boat slowly through calm water is but slight in comparison with the shove and lift which we have to give in order to bring the boat down to the water. On the water the boat is relieved of its weight and becomes buoyant; on land the weight tells; never, even in our dreams, do we imagine a boat drifting along the land.

The movements of animals are of these kinds. The body is the boat, its muscles represent the man, and its limbs replace the oars and boathook. Those animals which creep over the ground use their legs as the boatman uses his punt-oar, pressed against the rock, sand, or mud. Many animalcules, most worms, Crustacea, insects, and the vertebrates except fishes, press off in this way against some resistant medium. Burrowing animals lay hold of the sides of their retreat with hooks and claws as a boathook can be used to draw craft along river banks—of such are worms, many Crustacea, and insects. Swimming animals undulate the muscles of their back and tail as an oarsman twists a scull in the stern of a boat and lays hold of new columns of water with the blade first in one direction and then in another. In this way, bending the body from side to side into S and Ƨ shaped curves, the tail of the fish, the body of water-worms and of aquatic larvæ, grip a mass of water, and, using this as a resistant mass, bring the power of their muscles to bear upon it momentarily, then, instantly twisting into an inverse curve, grip a new mass, and so gain a new forward impetus. In a somewhat different way

the broad tail of a dog may be seen lashing wildly from side to side in the effort of steering round a turn when under full speed.

The act of rowing with a pair of oars leads us to a partial understanding of that perfect and difficult mode of movement—flight. The weight is brought to bear on the oar at the rowlock; the fulcrum is the advancing blade, and the power is applied at the handle. But, though far more clumsily, we can also row by facing forwards, grasping the oar outside the rowlock, and paddling. It is in that position that birds exert their muscular force; whilst in insects there is a muscle pulling on the inside of the rowlock for the forward stroke, as in ordinary rowing, and another on the outside for the backward stroke. In both cases the weight and inertia of the animal have to be supported by the attachment of the wings to the body; the muscular force is applied near that inner end, whilst the fulcrum, or point of support, is near the tip of the wing, which lays hold of the elusive columns of air, lifts the body, and, twisting like the sculling oar to avoid the eddy, falls slightly, grips a new column, and presses off against it. The faster the wing beats the better grip of the air does it obtain; for, as we know by motor travelling, air becomes almost a solid medium to cut a way through when our speed raises its resistance to a great amount. 'Feathering' the wing, therefore, even more than the similar trick with an oar, becomes a necessity if a bird is to get its wing up and to the front for another of those

powerful down strokes that give effectiveness to its flight.

But whilst we may in this way gain some acquaintance with animal movement by the analogy of a boat, there are features in the build and movements of animals not easily paralleled. A boat is a stiff unyielding structure, whilst an animal is provided with mobile muscular walls, which elongate and become thinner, or contract and thicken. Thus we may see worms, leeches, and caterpillars extend their bodies and, laying hold of some projection, draw themselves up to it, measuring in this way by looping movements the ground over which they travel, and so earning the sobriquet geometers ; or, by more rapidly repeating the movement, the separate events of tension and extension become merged into a continuous gliding. Thus the snake uses the special scales arranged down its belly as projections for performing those rippling movements by which it almost swims over the ground, and in so doing helps the forward movement by lateral undulations of the tail.

A method commonly employed amongst lower animals, and one that has no analogy in the working of a boat, consists in the expulsion of water from their bodies, and of a consequent rebound in the opposite direction. By this means jelly-fish swim in a series of jerks, which are due to the hollow bell or bell-clapper alternately expanding and taking a draught of water, then contracting and expelling it.

In a similar manner cuttlefish, octopus, and the

nautilus inhale deep draughts of water under their gill-covers and expel them through a funnel, strongly when at rest, violently when they wish to make a great backward leap. Many aquatic insect-larvæ, for instance those of dragon-flies, continually inhale draughts of water, and merely increase the force with which they expel the draught when they wish to make a darting movement. Prawns and lobsters leap backwards by a somewhat different artifice, laying hold of the water by the broad, concave under-surface of the tail, and then bending this smartly beneath the body.

Another mode of motion is that adopted by starfish and sea-urchins. The five arms or five hoops that surround the bodies of these creatures are provided with serried ranks of hollow tentacles ending in suckers. When the starfish wishes to move it advances one arm, stretches out the suckers belonging to it, and draws the body up behind. In the same way a sea-urchin emits long slender tentacles from its shell, and, advancing these, draws the body in tow. The brittle-stars which have such tentacles but no suckers at their tips, stretch out one arm in the direction they wish to follow, and, using the others as fins, strike the ground with a backward sweep, and shuffle over it in an ungainly fashion.

The movements of animalcules : Ciliary movement.—The movement of most animalcules is due to minute elastic hairs, which act as so many oars projecting from the body. Unlike oars, however, these

hairs derive their force not from a muscle connecting them with the body, but from an inherent flexibility, conferring on them the power of beating more rapidly in one direction than in the reverse; and as they maintain this vibratory movement with almost perfect constancy, rarely stopping to rest, still more rarely reversing their action, the body of the animalcule is carried through the water in a direction opposite to that of the more forceful stroke. If we imagine the body provided with a membrane which bends rapidly into a curve, straightens backwards, and again bends forwards, we should have in this membrane an organ acting not unlike the tail of a prawn or the effective bend of a fish-tail. Now let us imagine the membrane to be composed of hairs which flex and straighten of their own accord; then, if close set and synchronous in their stroke, their effectiveness in propelling the animal would hardly be less than that of a continuous membrane, and as the animalcules are excessively minute aquatic creatures, very small hairs, exerting a comparatively weak force, are sufficient to move them.

These hairs, or 'cilia,' as they are called, from a supposed likeness to eyelashes, are not confined to animalcules. They are found on the bodies of flat, gliding worms of our streams and ponds and on the foot of snails. They are the means whereby the minute young of all sorts of marine animals, which crawl or walk when older, swim about. The sea-jellies, eggs of worms and snails, hatch out as micro-

scopically small creatures, which even before birth spin round inside their egg-capsules by the aid of these cilia, and when out in the water glide through it by their aid ; and the bodies of zoophytes and corals, sea-mats and sea-mosses, of oysters, scallops, and cockles, which appear so hard and motionless when old, are rippled when young by the constant play of the waving bands of cilia that, aided by the currents, enable them to swim from the depths to the surface and from the open sea to the shore.

Cilia such as these are not confined to the surface of animals, nor is their only use that of locomotion. If we buy a pennyworth of mussels from a fishmonger, and place them in a dish of sea-water, the shellfish will soon open their valves and protrude their yellow skin fringed with tentacles. If a little Indian ink is added by a pipette, a movement in the water previously invisible will be rendered clear. The ink will be drawn between the tentacles into the valves ; something is at work inhaling a current of water. If now we open one of the mussels and cut off a piece of one of the yellow gills and place it in the water, the reason of the current will be made clear. The morsel of gill begins to move steadily along the bottom of the dish, as though endowed with independent life, and, if held up to the light in a glass dish and examined with a magnifying-glass, the filmy margin due to innumerable cilia can be seen. These vibrating rods, which when held by the weight of the intact gill sucked in a current of water, now, when attached to

a small fragment, cause this to move. Mahomet, as it were, comes to the mountain.

But the gill of shellfish is not the only place where cilia are found inside the bodies of complex animals.

Right up through the invertebrates and vertebrates, with the curious exception of the insect, spider, shrimps, and millepedes, cilia occur in some part or other of the internal organs. Even in ourselves the cavities of the nose and windpipe, of the brain and spinal cord, are lined with these vibrating rods, which bear witness to a community of substance which links us with the animalcules themselves.

As the organs of movement, whether displacing a minute creature or sluicing a fluid inside a large one, these cilia bear witness to the deep-seated cause of movement. Their activity is innate. So long as they are bathed by water or their natural medium, their movement is only indirectly controlled by the action of the body, or even by its presence. If detached, as they frequently are, from the dying body of spherical jelly-fish (fig. 2) that come drifting to our shores in summer, their movement continues for a time unchanged in strength or pace ; and while able to survive severance from the body temporarily, they are equally their own masters in the starting as in the maintenance of that unresting beat. Small wonder that organs so self-contained have been treasured, and that scope for their energy is found in highest and lowliest alike.

Yet all movement partakes of this mysterious,

innate character, self-caused and self-sustained. Undisguised as is the control that the nervous system exerts on our hearts, there is a cause of the heart-beat that lies in the organ itself, and not in any governance, however subtle and effective it may be. The fundamental spontaneity of movement is disguised, controlled, and rendered effectual in a hundred ways, from the obvious exercise of our will upon voluntary movement to the drilled soldier's unthinking response to the word of command, the unconscious acts of sleep and the automatic actions of animals. But underlying that controlled muscular force is the older, innate contractility perfected in one special form—ciliary movement.

Evolution of locomotor organs in animals.—In a lowly organism, such as an earth- or water-worm, the body consists of a muscular tube capable of elongation and contraction, and of lateral undulating wriggling movements. It is divided into rings, each of which bears a number of hooks for the purpose of creeping over the ground. In the more complex annelids, as these creatures are called from their segmented bodies, each ring grows out into two pairs of leg-like processes, whereby the efficiency of progression over ground is increased. Special muscles to move these limbs are formed, and the limbs themselves, in addition to bearing hooks, possess a leaf-like outgrowth. Pairs of appendages occur on each segment, and by their rhythmical action perform the part of oars, sculling the body through the water, as

well as enabling it to punt over the sea-bottom or to climb up burrows of earth (fig. 35, p. 200).

Among Crustacea we encounter precisely the same arrangement. Paired appendages are found on each segment, but now, being placed nearer together on the under-side of the body, their action is stronger and more precise. Moreover, the appendage is divided into inner and outer divisions, the outer one bearing the leaf-like structures and the inner branch becoming jointed and lobed. Such animals swim either on their backs by strong sculling movements inwards and backwards, or (*Daphnia*, fig. 24), standing vertically, they tread the water, rising at each stroke and falling slightly between the strokes. In higher Crustacea the outer division disappears from the limbs of most segments, and the inner one is converted, in the middle of the body, into a substantial jointed leg, capable both of clinging to holdfasts against currents and of supporting the weight of the body in walking; but the original character of the limb is seen in the swimmerets found under the tail of prawns and lobsters. These still beat from before backwards and ensure the forward swimming of the animal. Thus the body becomes divided into three portions—a head provided with jaws and antennæ, a firmer middle part for walking, and a flexible tail for swimming. The highest Crustacea, crabs, depend altogether on the mobility and strength of their legs for walking or swimming. In these animals the swimmerets are turned to other accounts, and are chiefly used for

the carriage and protection of the eggs, or, in hermit crabs, for grasping shells.

In insects we find a great variety of modes of motion. Their larvæ, terrestrial or aquatic, recall

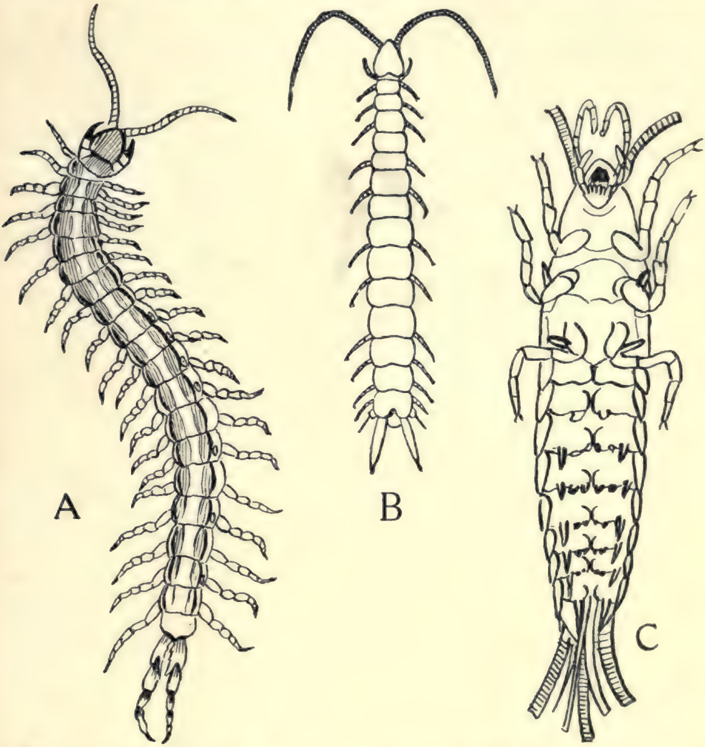

FIG. 6.—Illustrating the common starting-point of both Centipedes, or many-legged air-breathing animals, and of the insects with six legs. A. A Common Garden Centipede (*Lithobius:* from Koch's 'Myriapoden'). B. *Scolopendrella*, the connecting link between A and C.—(*After Lang.*) C. A primitive Insect (*Machilis*) found under stones and on the seashore. It shows the typical six-legged condition, but traces of the abdominal feet are shown by the minute spines.—(*After Oudemans.*)

the less complex worms in their simple muscular bodies, in their wriggling movements that serve for swimming, and the looping or stretching evolutions by which they creep. Their bodies, too, are subdivided into rings or segments, which bear a certain number of appendages arranged segmentally. These limbs, as we pass from the lower forms, such as *Scolopendrella*, to the higher insects (fig. 5), become definitely limited to three pairs for progression, and thus entail a correspondingly greater nicety of balance. The body becomes divided into three portions and is balanced about the middle one of these; carrying, in fact, to a further degree the division of the body into head, thorax, and abdomen, already seen in Crustacea. It is from this middle section of the body that the wings arise. Vertically over the second and third legs, pouch-like outgrowths of the body-wall form two pairs of flattened lamellæ, strengthened by ribs and veinings like leaves. The arrangement of the muscles that raise and depress the wings is a most complex one, but consists essentially of a double lever, both elevator and depressor acting vertically but on opposite sides of the fulcrum. These muscles are of great size and power, and where the wing meets most resistance and does most work, namely, at its front edge, it is stiffened by a selvage of veins.

To solve the problem of flight the economy and distribution of weight, the intensity and application of the muscular power have to be completely studied.

The body requires to balance about the middle,

and the wings to strike so that not only an upward but a forward or turning movement may be produced.

FIG. 7.—A Swallow on the wing, to show the arrangement of the wing and tail feathers in flight.—(*From a specimen in the Manchester Museum.*)

FIG. 8.—Greater Horseshoe Bat.—(*From a specimen in the Manchester Museum.*)

This is done by the wing-muscles not only producing an up-and-down stroke, but rotating the wing so

that its tip describes a figure of eight between every two up or down strokes; and in so doing uses the effective stroke for forward movement, just as a boat's sail, set at any angle with the wind, plays off the greater part of its breeze into a propelling force brought to bear on the front edge of the sail. For turning, the two sides of the body require to act independently, and to lower the wing on that side towards which it is desired to turn. The intensity and rapidity of muscular vibration during flight are extreme; indeed, the efficiency of insect muscle is quite extraordinary, both for strength, mobility, and persistence, and the wing-muscles are the most perfectly qualified of any in the body for sustained control and strong action.

We have only to watch a hovering fly in still air, or attempt to see a humming-bird hawk-moth flash, hover, and dart as it passes over flowers like a sunbeam, to realise that such insects have brought flight to a degree of perfection that seems astounding, unnatural, and unnecessary. So far are we behind the meanest fly in agility that we marvel, if at all, very much as a savage at machinery.

The problem of effectively using two pairs of wings simultaneously is, however, too difficult for most insects, and we find a tendency in many groups for the reduction of one of them. Like a boat sailing just astern another, the back-wash and eddies in the air caused by the front wings render the effective working of the hind wings a great problem. Never-

theless, the supreme exemplars of flight—dragon-flies and hawk-moths—are amongst four-winged insects, though even in these the hind wings tend to become smaller than the front ones. In most moths a hook links front and hind wings together, and the absence of this hook serves to distinguish butterflies from them.

In beetles the fore-wings are converted into shards or covers, held stiffly in flight, whilst the movement itself is entirely due to the hind-wings, which are curiously bent near the tip, so that we do not wonder that few shard-bearers are good fliers.

In bees and wasps the fore-wings are strongly developed and securely hooked on the front edge of the other pair, which in flies become reduced to balancers. They take no part in flight, but are converted into highly sensitive, nervous organs.

Movements of vertebrates: I. *The adaptations of fish.*—In vertebrates, the problem of movement in water, on land, and in air has been solved time after time. There are walking and flying fish, swimming and darting lizards, gliding and swimming snakes; and winged reptiles, though now extinct, were once abundant. Birds fly both in water and air, whilst bats, amongst mammals, are almost as exclusively animals of flight as whales and seals are animals of the water.

In the lowest fish, as in worms and insect larvæ, the body is essentially a muscular tube, capable of being thrown into wriggling, eel-like movements, by which pressure is brought to bear on the water at each

concavity. The tail is provided with a fin, shaped like the propeller of a steamer, by which its grip of the water is increased. In forward movement the body and tail of the fish are thrown into two or more curves, and as the body straightens, and before it takes an opposite curvature, the pressure of the tail on the water at the hollows, and especially the grip of the tail-fin, is greater than when the reverse curvature is obtained. The straightening stroke is more powerful than the bending one. Moreover, the tail does not merely undulate, but twists about its own axis, meeting the water first with one of its flat surfaces as it straightens, then feathering as it prepares for the next stroke, and again straightening out with full force of the opposite surface and the expanded fin. The swirl helps the fish to gain additional purchase, the eddy helps it to elude the water and eases the feathering stroke.

In order to render these undulations more effective the swimming-muscles that run down the body start from an elastic spinal rod, which gives them a central origin, and form not a continuous sheath, but a segmented mass of bundles, each bundle being bent into a V or W shape, with the points turned towards the head. The skin into which these muscle-bundles are inserted is elastic and lubricated; and if scaly, the points of the scales project backwards, so as not to impede the forward movement. Moreover, the amount of muscular tissue is increased by reducing the space in which the internal organs are packed to

a small compass, and converting the tail into a solid mass of muscle—the main driving power of the fish. And, further, since the animal floats, or is but slightly heavier than its own bulk of fresh water, the vertical strain on its body is reduced to a minimum, and therefore the vertebræ may remain—as in sharks—gristly or undemarcated.

The provisions for altering the direction of movement are of the nicest adaptation. Since in most fish the muscular arrangement is employed for horizontal progression, and gives no great facility for change of depth, a special provision is made to meet this want: an air-bladder under the backbone is developed, the gaseous contents of which can be increased or decreased in amount, and so the relative weight of the fish increased where descent is needed and reduced where ascent is required. To this end also the paired fins are employed, as well as for turning and steering; and as the use of these two pairs of fins incurs difficulties of the same order as those already seen in insects, we find in fish, as amongst insects, a tendency to reduce one pair—the hind fins—and to give them another office, whilst at the same time enlarging the fore-fins in accordance with the increased work of guidance thrown upon them; to which work must be added the maintenance of the unstable equilibrium, over which they keep constant guard.

The vertically compressed shape of a well-built, active fish is such that it can never remain upright and still. It is ceaselessly making small

adjustments to overcome the tendency to float upon its back. As a help towards steadying the body it has developed fins along the middle line of the back and tail. These 'median' fins act as keels or centre-boards. They are supported by a series of spines, which can elevate or depress the membrane they support. The first of these spines is often stronger than the rest, and acts as a cut-water. Moreover, to diminish the resistance of such fins in a turning movement the spines can be lowered, so that the fin collapses, and raised again when the new tack is begun. Thus rapidly can a shark unstep the peg that stretches his dorsal fin and ship it again in the notch at its base.

If such complex adjustments are needed by active fish, we do not wonder that a change in the shape or attitude of the body has been developed in those which seek their food on the bottom, or wish to escape the constant exertion of a mid-water life. Of these, the flat-fish and skates are the most remarkable. Connected with the dory family by many ties of structure and mode of occurrence, the sole and plaice, turbot and dab, agree with their relative, the John Dory, in being flattened, but differ in resting on or in the sand instead of hovering over it. It might be thought that this result was merely due to a compression of the body parallel to the ground, but examination shows that both eyes in a flat-fish appear on the upper coloured side, that the mouth is awry, and that the skull-orbits are also skew-whiffed.

In fact, a flat-fish, which begins life as a round fish, balancing vertically, slips on to its right or left side, which then becomes the colourless under surface, whilst the other side is converted into a variably tinted upper surface. The eye belonging to the side upon the sea-bottom has rotated owing to a twist of the orbit to the upper surface, upon which both eyes thus appear to lie, and the animal, though flapping through the water by vertical instead of horizontal strokes, is still using its muscles relatively to itself as they were employed before rotation.

The skates and rays attain their flattened shape by compression of the more rounded body seen in sharks and dogfish, and by an enormous extension of the first pair of fins to form the wings, which, growing and fusing with the body, give rise to that diamond shape so characteristic of the skates. These fins are now the chief organs of locomotion, and suitably so, since they are specially adapted to a vertical movement such as the skate requires, whilst the somewhat slender tail gives the propulsion necessary for forward movement.

The attempts that fish have made from time to time to walk and fly are of great interest. Many balance themselves on their two pairs of fins and grub or nose about the rocks under water ; but owing to the unjointed nature of their limbs, this attitud is extremely difficult to maintain on land. Yet here and there shore-fish have adapted themselves to a temporary land life. The gobies that swarm on

our coasts have a relative on Eastern shores that hops with great vigour on its front fins, keeping its taïl in water. A perch with the same implements manages to shuffle up overhanging boughs, and the bat-fish has actually developed an elbow-joint, whereby it can rest its weight on the flat part of the fin. But no amount of ingenuity has conferred on any fish we know the ability to walk freely.

On the other hand, at least two groups of the most active swimming fish have developed that power of leaping into the air, often found in the most varied groups, into a sustained, gliding movement which resembles flight. For this purpose the flying-fish employ their powerful breast fins, which they keep spread out like a parachute. By the aid of this aëroplane their descent is delayed; and so powerful is the initial jump from the sea into the air that, with a favouring breeze, they may rise on to the deck of a steamer or go clean over a fishing-boat.

II. *The adaptations of terrestrial vertebrates.*—It is, however, only when we ascend above fish to the higher vertebrates that we find the problems of movement on land and in the air completely solved.

On land, weight enters into the problem. Support, unneeded in the sustaining water, becomes now a necessity; and in order that this weight may be upborne and moved, all the skeletal parts require to be denser, both on account of the vertical strain they support and the greater muscular tension requisite for movement. The limbs become props whilst

still organs of locomotion. To combine the advantages of short limbs for support, and of long ones for speed, is only one of the problems that press for solution. To relieve the muscles of the body's weight, a vertical pillar-like leg is necessary. To gain the leverage needed for propulsion, a bent leg capable of straightening out is requisite. Hence we find that great size in quadrupeds involves columnar limbs, with the segments placed vertically, as in elephants; but in smaller animals, such as horses, the fore-limb only has this linear character, and bears greater weight, whilst the hind-limb is thrown into a zigzag form when at rest, and into a straighter line in movement. Movement and rest in an erect position, as in man, some apes, and birds, require a still greater change in the disposition of the weight, muscles, and ligaments. The mass of the body now falls upon the hind-limbs, which therefore become straighter than in quadrupeds, and the spine is sustained by ligaments that relieve the back muscles of an otherwise constant strain. The muscles of the shank become more strongly developed, not only to sustain but also to propel the weight now thrown altogether upon them. For these purposes also the foot is not elongated into a slender organ delicately poised on the toe-tips, as in many active quadrupeds, but is flattened and the heel brought down to the ground. Lastly, as an additional prop for support, the tail may be retained and thickened, as in the kangaroo.

A survey of the vertebrates shows how the changes

to meet the needs of terrestrial movement have been brought about from fish. Throughout the Amphibia, with a few interesting exceptions, two pairs of limbs corresponding to the paired fins of fishes serve in various ways. In the newts the body is still fishlike, but the limbs have acquired that division into upper, middle, and lower segments (arm, forearm, and hand, thigh, shank, and foot), that is so strikingly a character of all the higher vertebrates.

The movements of these animals and their relatives, the salamanders, are exceedingly slow. The legs are short and bent—good, therefore, neither for bearing weight nor as levers ; and the only powerful stroke is the fishlike, lateral bending performed by the tail under water. Frogs and toads, however, show an advance in their locomotive powers by the leaping and thrusting power of their long bent hind limbs.

In the reptiles the powerful longitudinal muscles of the back and tail, so characteristic of fish, are still employed, and serve to assist the feet, which are short, bent, and flattened. The movements of these animals consist of short, violent rushes from point to point. For sustained, rapid action neither the limbs nor the disposition of the weight is suitable ; and reptilian life enjoys extreme speed for short periods, alternating with immobility for long ones. Their degeneracy is shown in the disuse of limbs, a distinctively fishlike character, which we find in snakes and many lizards. As compensation for this loss the scales of the belly become enlarged, and into them are inserted the ends of the

very numerous ribs. When the snake desires to move, the ribs are raised one after another by the lateral body-muscles, and the scales, pressing against the ground, serve to propel the body forward. At the same time, owing to the singular flexibility of the backbone, the lateral, eel-like movements bring the lithe body over the ground with great rapidity.

Although the reptiles of to-day are inferior to those of the past, which walked erect, ran doglike or flew, there is at least one group among them—that of lizards—which is at its prime, and amongst these one or two may be specially mentioned.

In zoological gardens geckos may sometimes be seen. They are small, extremely active when roused, and provided with padded adhesive fingers and toes. By the aid of these pads geckos are able to perform the strangest feats. When hunting for flies they run up and down papered walls, and even glass windows. So sure is their hold that they can run up a wall, bend over, and slide along the ceiling. Like other lizards, geckos often lie motionless for a long time, but evade capture not by a run that can be seen but in a flash of gliding. Such geckos are household pets in the East. But perhaps the most agile of all is a lizard found in Malay, which is so active as to run securely over the tops of grass shoots.

In mammals the organs of movement are far more effective. The tail is reduced and the longitudinal muscles of the back—heirlooms from fishes—are employed for the work of the shoulder and hip. The

body is carried clear of the ground and supported mainly on the straight fore-limbs, whilst propulsion is effected by the more bent hind-limbs, which are straightened by very powerful muscles and tendons; and to provide a sufficiently firm *point d'appui* for these the hip-girdle and vertebræ of the small of the back are greatly enlarged. To give them additional leverage the bones of the shank and foot are elongated. To ensure elasticity of tread, fleshy pads are developed in carnivores under the middle joint of the toes, and in cats the claw-bearing ones are held back in walking by means of a tendon in a protecting sheath, and only dart out by the action of prehensile muscles. For support on slippery ground the heel is raised still higher than in carnivores, and only the end joint of the toe converted into a horny hoof. Among these mammals, the so-called Ungulates, a remarkable reduction in the number of toes has taken place. Instead of the five which only elephants have retained, ruminants have only two—the third and fourth; pigs and rhinoceros four, peccaries three, and horses one. The cloven hoof, characteristic of those that chew the cud, alone touches the ground, but traces of the second and fifth toes are seen in the deer, and are of use in spreading out the animal's weight when soft ground is encountered.

Of the many special modes of motion adopted by mammals only a few can be mentioned.

In monkeys and apes the habit of climbing and of sitting nearly erect throws the weight of the body

more and more on to the hind-quarters, and the arms, thus relieved of their primitive supporting function, are used for prehension; whilst in South American monkeys the tail is converted into a sensitive fifth hand for grasping boughs and giving support. In this way many of the Quadrumana have lost the power of rapid and effective running on the ground, and have acquired a wholly new arboreal mode of life and a new dexterity in the performance of their wonderful gymnastics. For grasping the twigs monkeys employ the hand as we do, with the grasp between the thumb and the palm, and the most arboreal of all are either thumbless or their fingers partially adhere, so that their limbs are converted into mere grasping hooks.

III. *Adaptations for swimming and flight in mammals.*—The most remarkable adaptations to aquatic and aërial life are found in a few groups of mammals; amongst the seals and whales for swimming and the bats for flight.

Mammals are so emphatically land animals, only swimming by the aid of their limbs to reach new feeding-grounds, that the existence of two aquatic groups, one of which passes the whole of its life in the sea, is a striking fact. So different are whales and porpoises from ordinary mammals that the idea of their being fish is still widely prevalent, and, though erroneous, is intelligible by the many fishlike characters which these animals possess.

The seal is amphibious, spending the greater part

of its time in the sea near the coast, and only going ashore to rest and to bring up its family. The body is thick in front and flattened behind. The tail has almost disappeared, and on either side of it the hind limbs are held rigidly out at full length. Between the fingers and toes the skin has grown so as to convert the fore-limbs into paddles and the hind-limbs into a propeller. On land a seal shuffles awkwardly on its belly, only using its hands if pressed; but at sea the flattened hind-limbs, together with the lateral muscles

FIG. 9.—The White Seal (*Lobodon*) of Antarctic shores.—(*From a specimen in the Manchester Museum* × $\frac{1}{28}$.)

of the body, enable it both to swim with great ease and to ascend periodically to the surface for air. The forepaws are used for steering.

The porpoises and dolphins, the baleen and toothed whales, are as perfect in the art of swimming as any fish. Their bodies, denuded of hair, are usually of a build so completely adapted for cleaving the water that boat-builders could design the lines of their craft from models of whales. The head is a cone pointed in

front; the neck is not marked; the back rises in a curve that gives easiest passage through the water, and finishes off behind in a tail flattened from above downwards. The general aspect and build resemble those of a free-swimming fish, but, whilst fish have a vertically flattened tail for horizontal movement, whales require a horizontally compressed tail to make those periodical ascents requisite for breathing air.

Forward movement is maintained slowly or at a prodigious speed by the huge longitudinal tail-muscles swaying the body from side to side and making effective undulations on the principle of a fish. The legs are hidden and rudimentary, and their muscles are added to those of the back: whilst the arms are converted into steering-paddles as near a return to fins as is well possible. The fingers, though still five in number, are composed of more joints than the otherwise universal number, three. The nails have disappeared. Weight and size, no longer limited by the supporting power of the limb, may reach colossal dimensions; whales of eighty feet in length and weighing eighty tons still abound.

To acquire powers of flight is perhaps an even greater feat than the conversion of a terrestrial animal into a whale. Amongst various groups of mammals the first stage of flight—the arrest of the body in a gliding descent, instead of in a straight fall, has been accomplished. Some of the opossums have extended that fold of skin which allows movement of our arms at the armpit, into a membrane that stretches from

the arm to the toes. By its aid their leap off a branch takes the form of a rise into the air, then a gentle downward curve. Amongst the squirrels two forms of such 'aëroplanes' have been devised independently, and by the aid of these, flying leaps can be made from tree to tree without descending to the ground. But it is only amongst the bats that true flight has been attained. Like huge moths, these animals come out every summer evening from the ivy, hollow tree, or barns in which they lie hidden by day, hanging downwards from some projection, often in great clusters, with their head enfolded by the wings.

These wings are folds of skin stretched from the altered hands and arms to the legs. To increase their extent the fingers are drawn out to an immense length and the wing-membrane continued to the very tips, leaving only the thumb free. The muscles for flight are strongly developed, and, as in a bird, lead to the formation of a keel-like breast-bone, from which they arise (fig. 8, p. 41).

The unerring certainty of a bat's flying and alighting movements is a marvel of skill. In a room they explore the furniture and recesses, sail through passages a few inches wide without touching anything, dive under a sofa, and, turning a somersault, alight on the webbing head downwards, ready for the next flight. Then they spring clean into the air, even from a flat surface, and are on the wing at once.

The inclusion of the hind-limbs in the formation of the wings has the effect of bending the knee out-

wards and backwards, instead of forwards as in all other mammals, and this, together with the pre-occupation of all the hand but the thumb, renders walking difficult. On a flat surface some bats cannot walk; but others, such as the long-eared bat, progress in the usual way—first a hind-foot is advanced, then the fore-foot of the same side, followed by similar movements of the opposite limbs.

IV. *The adaptations of birds for flight and perching.*—But it is amongst birds that we encounter the greatest freedom and most sustained powers of movement. To gain the dominion of the air by the use of wings, whilst yet retaining the power of balancing on the two legs, is a double problem of the utmost difficulty, and in the solution every part of a bird's body has undergone some adaptive change. What a feat this is we may judge on considering the imperfect attempts man has made towards constructing an efficient flying-machine, though he has tried for a century. But in a bird, so little cumbrous is the mechanism that its sails can be folded evenly with the contour of the body; so efficient, that flight at express-train speed and sailing in great winding circles with outstretched, motionless wings are both performed with the same easy mastery as perching or hopping; so well guided, that migratory birds sweep through immense tracts of air and reach their destination with a punctuality so sure that the Persian calendar is based on their arrival..

The general shape of a bird fits it for rapid flight.

The pointed head serves to form a passage through the air, into which the rising slope of the body follows, whilst the falling slope of the tail allows the air to glide off rapidly. The weight is taken off all the peripheral parts and centred in the massive muscles of the breast and the parts adjoining ; yet so delicately poised that by extending its mobile neck the bird, gliding with outstretched wings, descends where it will. By letting the legs fall the head is thrown upwards, the point of balance being thus moved slightly forwards or backwards without the aid of the wings. These wings or sails are essentially fore-limbs, similar to our own, but modified in every feature for the needs of flight. The arm rises upwards and backwards, the forearm forwards and upwards, the hand backwards and upwards, forming at rest a zigzag, with the elbow pointing backwards and the wrist forwards, but in action extending into a straight line,

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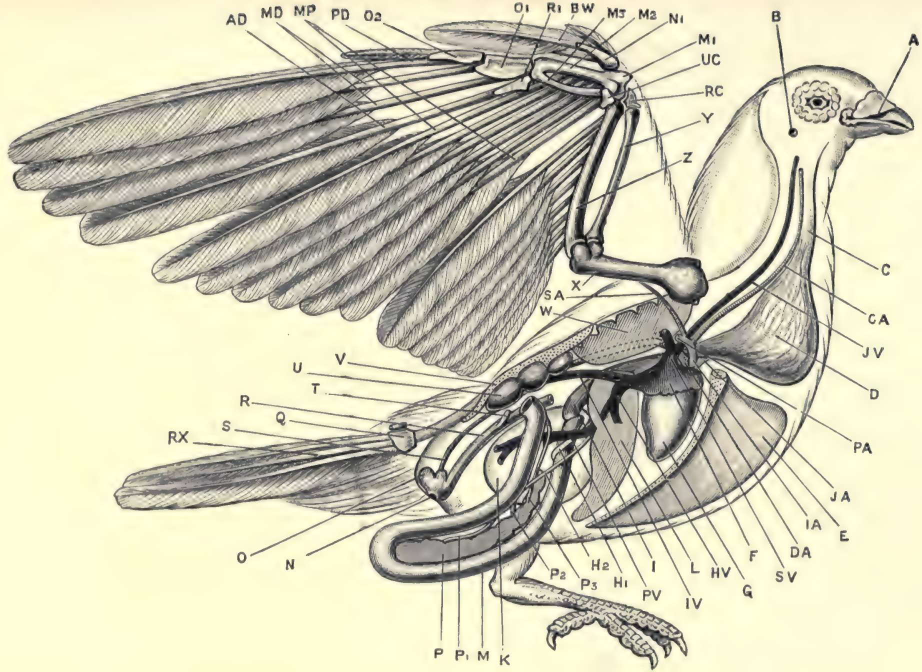
FIG. 10.—The Pigeon. Dissection of the male from the right side. Half the liver and the greater part of the intestine have been removed. In the right wing, the bones and the arrangement of the primary and secondary feathers are shown.—(*From Marshall and Hurst*, '*Practical Zoology.*')

A, nostril. AD, ad-digital primary feather. B, external auditory meatus. BW, bastard wing. C, œsophagus. CA, right carotid artery. D, crop. DA, aorta. E, keel of the sternum. F, right auricle. G, right ventricle. HV, hepatic vein. H1, left bile-duct. H2, right bile-duct. I, distal end of stomach. IA, right innominate artery. IV, posterior vena cava. JA, left innominate artery. JV, right jugular vein. K, gizzard. L, liver. M, proximal limb of duodenum. MD, the two mid-digital primary feathers. MP the six metacarpal primary feathers. M1, first metacarpal. M2, second metacarpal. M3, third metacarpal. N, cloacal aperture. N1, first digit of manus. O, bursa Fabricii. O1, proximal phalanx of second digit of manus. O2, distal phalanx of second digit of manus. P, pancreas. PA, right pectoral artery. PD, pre-digital primary feather. PV, portal vein. P1, first pancreatic duct. P2, second pancreatic duct. P3, third pancreatic duct. Q, pygostyle. R, rectum. RC, radial carpal bone. RX, rectrices or tail-feathers. R1, third digit of manus. S, ureter. SA, right subclavian artery. SV, right anterior vena cava. T, rectal diverticulum. U, kidney. UC, ulnar carpal bone. V, pelvis. W, lung. X, humerus. Y, radius. Z, ulna.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which, moving freely at the shoulder, sweeps the tip of the wings in spirals. Length of wing is given in two ways: by elongation of the arm and hand, as in storks, or by increase of the feathers in length, as in swallows; and as we saw that in the fleetest mammals length of limb and reduction in the number of fingers or toes went together, so in birds we find that only two of the usual five fingers are used for the support of the greater part of the wing. The skin between these fingers and at each side of the wing grows into flaps, which, being covered with feathers, form an aëroplane triangular in surface-outline, and yet curved so as to furnish a concavity below and a convexity above. Upon such a membrane, only flying leaps like those of squirrels could be carried out. To convert the feathered membrane into a true wing it must be provided with muscles sufficiently powerful to lift the bird into the air; and since not only upward but also forward movement is required, the direction of the wing has to be so inclined to that of the air-current as to convert the oblique thrust into a large, forwardly-acting component and a small, inactive one at right angles to this, just as a boat's sail plays off the force of wind into a propelling and a drifting force, or as an insect's wing or fish's tail solves the same problem of resolution. Hence the need for the powerful breast muscles, mainly for depressing the wing not in one vertical plane but obliquely downwards and backwards. And since the efficiency of stroke is guided by the speed of the bird relative to that of the

air, in a calm rapidity, in a breeze slowness, of successional stroke will characterise the beating of the wing. Further, since the resistance of the air increases with great rapidity as the speed freshens, the wing after one downstroke has to be lifted home edgewise for the next, so as not to stop the momentum; and this turning movement brings the wing not full-sail up to the vertical, but slews the front edge, somewhat flexed, to the front, and then extends it high above the head ready for another powerful sweep.

To gain support from the air and to assist flight, the details of shape and feathering of the wing are modified. The lower surface grips the air chiefly by its front edge and tip, and as a jib sail, though narrow and triangular, must be strengthened on its front edge, so good fliers need strong edge feathers and narrow, pointed wings. The feathers are elaborately airtight to enhance that grip, yet are disposed so as to allow air to flow edgewise between them and over the convexity of the upper surface as it comes forward. The difference in the width of the vane on either side of the feather's stem is not without its meaning, for, when a flat body is falling obliquely through the air, the pressure becomes greatest not at the centre but towards the front edge, which tends to rise. If, therefore, the front webs of the first eight flight feathers were equal in width to the hind vanes, the outstretched wings would tilt up and the bird's balance would be destroyed. It is to avoid this disturbance that the outer webbing of the feathers, upon which the main stress falls, is reduced

in width (fig. 8). The form, then, not only of the wing, but of every flight feather—hollow and sustaining below, rounded and unresistant above, short and rounded for more laborious flight, long and pointed for easy, sustained flight—has a definite significance for all the varied needs of birds and their more elaborate evolutions, such as sailing and soaring. And in those cases in which flight is abandoned and the wing, as in penguins, is converted into a fin, the feathers take on the form most suitable to the needs of an aquatic life and form scale-like coverings.

Flight, however, is not the only movement for which birds are fitted; and if the fore part of the body is exquisitely adapted to meet the requirements of aërial life, the hinder part is mainly a mechanism for terrestrial and aquatic existence, for running, perching, or swimming. Such a double adaptation is a rare thing in animals, and is only shared by insects. All others that specialise in movement—fish, whales, bats—have become incapable of rapid and sustained travel in an alternative manner. Birds alone are capable of both flight and bipedal movement.

The legs of a bird have a double office. They sustain and propel the body's weight, which is disposed so as to fall about the knee-joint.

For sustenance the limbs are pillar-like, and distribute the pressure over four divergent toes. For propulsion the joints are elongated, and the hip-girdle, or 'back' of the bird, affords a large area,

from which the powerful leg-muscles send down their tendons, which bend the knee and the toes, and, so doing, thrust the body forward. The thigh is short and the knee buried in the body's side. What appears to be the backwardly pointing knee is in reality the ankle-joint, and separates the shank from those bones which in ourselves lie flat, but which in a bird are drawn up to form a vertical column extending the length of the limb, and giving it additional power of movement. Just as in a horse or antelope great speed is gained by the larger joints of shank and foot bone, so in a bird the corresponding bones are drawn out into an elongated zigzag. In the most perfect runner amongst birds—the ostrich—the reduction in the number of toes and the elastic padding for treading over sand have followed precisely on the lines adopted by the camel.

The majority of birds possess feet suitable for perching or swimming, and the ease with which they securely alight, sleep resting on one leg, or paddle through water, involves a mechanism as perfect in its adaptation to these ends as is that of the wings for flight. Of the four toes usually present, one corresponding to the first of lizards is commonly opposed to the rest, so that the claw of the middle toe in front overlaps that of the hind toe and holds the twig between. Now by a labour-saving mechanism this hold, apparently so precarious, is rendered automatically secure. Along the front of the knee there runs a tendon which passes down the leg and ends on the under-side of the

toes. Any bending of the knee, therefore, tightens the hold of the feet; and this hold is rendered still more secure by another tendon which runs at the back of the leg and divides into three—one for each toe. When the bird perches, the weight of the body thrusts the knee out and the ankle back, and simultaneously tightens both sets of tendons, and through them the hold of the feet.

In swimming-birds this flexure is the means whereby the membrane between the toes is opened and brought to bear on the water; but, in order that the resistance of the feet may be overcome, when the forward stroke is to be made, the membrane is rendered capable of opening and shutting, and the toes are spread out during the swimming, or back-stroke, and brought together during the forward one. In a grebe's foot the vanes down the toes can be pulled out flat by the back tendon and turned down vertically by the front one. The foot of a bird, no less than any other part of its body, gives evidence of the most exquisite finish and usefulness.

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CHAPTER V

THE QUEST FOR FOOD

THE need for self-maintenance leads an animal to feed. To whatever end its energy is directed, loss of substance is incurred by its movement, and even by its rest. When we are lying down the breast still rises and falls, the heart beats, the blood flows, the glands secrete, digest, and store; the brain is not altogether still, and may plan in sleep works and compositions beyond the power of our waking selves to execute. Even the muscles, quiet as they seem, are doing internal work. By day and night, actively or restfully, the basis of life is used up and needs renewal. How to meet this urgent demand for material we have now to consider.

The source of animal food : the quest for plants.—The kindly fruit of the earth is the source of animal food. Directly or indirectly, animal life is dependent on plants, visible or invisible, and so great is the supply that a flesh diet becomes anomalous. The earth is covered with verdure ; the sea is fringed with weeds and teems with minute plants. Soil is the remains of the vesture that waves in the wind and water, held in a meshwork of moulds. Diatoms,

minute plants enclosed in flinty cases, surpass sand-grains in multitude; they encrust the shore, fill the beds of rivers, and, borne on the air, are showered down upon sea and land from the tropics to the poles.

The oldest and simplest way of catching food is that practised by the lower aquatic animals: sponges, corals, animalcules, and all encrusting organisms. It consists in drinking the water and sifting from it the minute organisms that abound therein. It is carried out by the aid of those minute, vibratile hairs or cilia which, originally used for drawing the animal through the water, now draw water through the animal. Into the vortex created by the beating of these organs will be haled from the surrounding catchment-area all those particles which cannot resist suction, however gentle; and as animal and plant spores abound in fresh and salt water during the spring and summer, the particles inhaled will consist partially, at least, of minute organisms, and upon these the sponge or coral is able to live. In a similar manner, barnacles throw out and draw in their casting-nets and collect the fine wreckage of the coast which constitutes their food.

Most of the animals that feed in this way are fixed, and when at the approach of winter the supply of minute organisms falls off, they have no means of leaving the coast or lake shore for more teeming water. In order that they shall not starve during this season, most encrusting animals lay up during

the autumn stores of highly concentrated nourishment, such as starch and oil, within their tissues. Having done this they hibernate, and such food as they require until the next spring is supplied out of these reserves.

The larger plants afford nourishment to larger or more active animals, and there is hardly a weed or flower or tree that does not support a varied assemblage of adherents. The tangles of submarine groves of seaweed and pondweed are cropped by fish and scoured by snails. Every part of land plants—the roots and young succulent leaves, the nectar, the sap, the fruits, wood, and even the galls—furnishes nourishment to insects and their young. Nor is the plant merely food to them. Shelter can be found in the innumerable crevices of bark and leaf. Air is afforded by the spaces and tubes that traverse the tissues. The very sheddings of plants are true windfalls for other creatures. The bud-scales of spring, the leaves and fruits of autumn, all the fine débris that rain down on to the earth beneath, are gathered by ants and birds, eaten by slugs, and remoulded by worms. Weed jetsam is similarly refined. The ebb-tide, that leaves the seaweed stranded in heaps, exposes the burrows of innumerable hungry scavengers in the sand. Each evening, when the tide serves, the sand-hoppers creep out of their hiding-places near high-water mark and begin their mazy dance in search of drift-weed; whilst myriads of smaller shrimps, each enclosed in a minute bivalve shell, career

unceasingly over their food. Dustman service is the lot of many. Earth and water are kept clean by their unwearied efforts (fig. 11).

In order to gather their food-plants, insects and Crustacea employ a similar series of mouth-part diversely shaped according to the special needs of each class. Their mouth is overhung by a mobile upper lip, and enclosed at the sides by a pair of appendages constructed on the same plan as the swimming or walking legs, but modified to form jaws, that

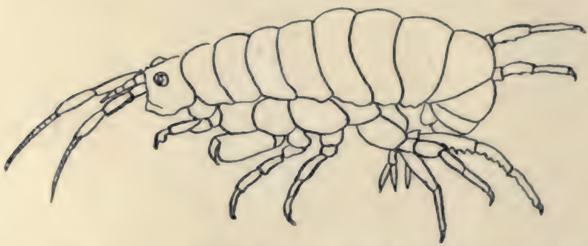

FIG. 11.—The Common Sand-Hopper (*Gammarus locusta*). A similar form is common in fresh water.—(*After Della Valle.*) × 4.

work from side to side and chew the food between them. Behind these a lower lip is formed by a pair of limbs that still show that division into inner and outer lobes that betrays their alliance with swimmerets; and usually there is added to these yet another pair of members of similar bifid nature. These parts of the lower lip were originally sensitive vibrating paddles, and their accustomed movements had to be but slightly altered to fit them for chewing and tasting, instead of paddling. Provided with these, insect and

shrimp can test the weed, cut out parts of their food-plant, and masticate it.

FIG. 12.—Tube-forming Sand-Hoppers (*Corophium*). The large specimen is a Male; the two others, partially concealed in their tubes of mud, are Females.—(*From Della Valle.*)

But as insects became adapted to subsist on the higher plants, their biting habits led to a great discovery. Once through the bark or leaf their jaws

would meet with a sweet, sticky sap; through the hole made more and more would rise. Such a fragrant bouquet no water plant possesses. Such a rising sap no seaweed or pondweed exudes. To be able to

FIG. 13.—A group of *Necrophorus* and *Aphodius* Beetles burying a Bird.—(*From a specimen in the Manchester Museum.*)

lick or suck now becomes the insect's advantage, for sap is not only more fragrant, but far more easily digested than almost any other vegetable food, and all manner of brushes, tubes, and tongues have been

evolved for the purpose. The lower lip is drawn out spoutwise to catch and then to drink or lap up the juice, or else becomes hairy to absorb it. Finally, of its two parts, that forming the tongue becomes

FIG. 14.—A small primitive Insect (*Orchesella cincta*) found under stones, representative of an early group of insects from which the sucking forms have since developed.—(*After Lubbock. Reproduced by permission of Lord Avebury from his Monograph, published by the Ray Society.*) × 10.

drawn out into a tube of marvellous complexity, up which the sap is pumped by a piston developed inside the throat.

When gathering honey, insects perform the memor-

able service of cross-fertilisation to the plants they visit. In the act of dipping the tongue into the corolla to tap the nectaries the insect dusts its head and legs with mealy pollen. Thus powdered, it flies to the next flower or another plant of the same kind, and when unfurling its proboscis strikes gently against the pillared stigma that stands central in the corolla and cross-fertilises it.

The advantages of cross-breeding over inbreeding are many and great. In vigour, colour, abundance of fruit, crossbred plants are superior to inbred ones. But since plants are fixed organisms, the pollen has to be borne from flower to flower, or from a male tree to a female, by one of the three moving agencies, water, air, or animals. Flowers are in the main devices to attract the notice of animals and to ensure pollination. Brilliancy of colour, definiteness of pattern, attractiveness of odour, serve to draw the curiosity of animals. The opening of strong-smelling plants by night entices nocturnal creatures to visit them. Of the numerous applicants drawn by this bounty not all are helpful. Sparrows confer no benefit on crocuses by their ruthless destruction of early blooms. Slugs are the gardener's greatest foe. But the great majority of flying insects are drawn, not to an indiscriminate destruction of the flower, but to the nectaries, or honey-sacs, which secrete the odour from within it.

The interaction between flowers and the insects that visit them is one of the most interesting chapters

in natural history. So intimately are they dependent on one another that some plants, such as certain figs and the Yucca palm, would die out were it not for a small wasp in the one case and a minute moth in the other, that serve, and alone serve, to ensure fertilisation.

Another method of obtaining vegetable food is that practised by snails and slugs. These animals browse on aquatic and terrestrial plants by rasping away the surface of the plant between their prickly tongue and horny upper jaw. This method is, on a small scale, the one adopted by ruminants, such as cows and sheep, which grip their food between the tongue and horny pad of the upper jaw, and in both cases the lips are used to bring the food to the teeth. But in the snail the tongue is covered with a ribbon bearing horny teeth, which as fast as they wear away are replaced by new ones, and the action of these teeth is not unlike that of the cutter in a lawn-mower, while the fixed upper jaw of the snail corresponds to the bar against which the cutter clips off the grass. By the aid of this rasping tongue snails and slugs are able to obtain food in almost all circumstances. The covering of slimy algæ on the seashore, the green scum that appears on pools and roadsides, the liverworts, mosses, fungi, lichens, and most of the higher plants, provide an endless store of provender. So great is the injury done by snails, without any counterbalancing advantage, such as many insects confer, that plants have sought to protect themselves against these attacks by various methods. So general is this

need for protection that every flowering plant possesses some means of defence: hardness or prickliness, irritating lime salts, or acrid and oily juices. Against the attacks of some slugs, however, even such defences as poison may fail. The great black *Arion* will eat almost anything; but all the slugs of our gardens are not equally to blame for the immense damage to bulbs, seedlings, and plants that is often set down to them indiscriminately. The field *Limax* and the keeled *Limax* are the two most culpable destroyers, and it is to these that the disappearance of bulbs is largely due. The great *Limax*, on the other hand, does not appear to touch green food, but subsists on moulds; the margined slug on lichens only. They forage night after night over the same beat, and return by day to the same hiding-places. Latter's work (quoted on p. 300) helps one to identify them.

Forest, moor, and plain support an abundance of mammals. Herbs are sought after by the largest and smallest of beasts. All the 'ungulates'—elephants, horses, cattle, and deer—are herbivorous, and live in troops led by an old male. Less imposing, but more numerous than these, are the rabbits, mice, squirrels, and beavers, great in their powers of destruction, though individually small, and some, such as harvest-mice, scarcely bigger than insects. Monkeys, where protected, as in India, become a pest, and not only destroy the fruit of the forest, but do immense damage to gardens.

The different ways in which mammals gather

their food are of interest. The majority use their teeth, which, in such cases, are chisel-shaped in front. All the ruminants press the grass between their tongue and upper toothless gums. The horse grasps with his lips, the tapir with the longer flexible snout which, in the elephant, is drawn out into a trunk of the utmost sensitiveness and strength, serving not only to reach up to lofty boughs for the juicier leaves, but also to overturn trees whose summits are out of reach. Squirrels and monkeys, on the contrary, use their hands for conveying food to the mouth.

The need for thoroughly chewing such food has entailed great modifications of the teeth and face. The long face of the horse is due to the lodgment of many grinders. The complex form and large size of these teeth enable them to act as a mill, those of the upper jaw fitting into the hollows and bosses of the lower teeth ; whereas, since the upper and lower jaws of the ruminants are not equally wide, the teeth act intermittently on one side first and then on the other. To equip themselves for encountering dusty herbage, the Herbivora have developed an elaborate arrangement for separating dust and pollen from the air which enters the nose in order to gain the lungs. The bones that form the framework and support of the nasal passages are converted into labyrinths, so that the air whirls round on its way to the lungs, and in so doing deposits the heavier particles on the sticky walls, as a ' separator ' divides the cream from the milk. The dust, pollen, and spores are then carried

outwards by the set of the ciliary current, which, as we saw, maintains an outgoing flow. The 'turbinals,' as these labyrinths are called, help in other ways, by warming and scenting the air, and serve to build up the long and stout face that distinguishes herbivorous animals.

Another means of rendering the food easily digestible is known as chewing the cud. The cud is not the herbage taken straight from the field, but consists of a mass of pulpy grass which has undergone partial digestion, and has been sent back into the mouth for a thorough mastication. All animals with a cloven hoof, except pigs, are ruminants, whilst those which have more than two complete toes or only one, are not provided with this singular mechanism.

Among the birds, devices of a much less complex kind are adopted for obtaining a vegetarian diet. But few birds subsist on leaves, for their innutritious character makes it necessary to gather large supplies in order to furnish even a small amount of food, and then it is only obtained at the expense of much hard mastication. For a bird such a diet is eminently unsuitable, since it neither wishes to overweight itself with a heavy meal nor has it teeth to grind with. Unlike the ruminants, which graze in safety, most birds appear perpetually harassed by real or imaginary fears, and need a light, stimulating diet to replace the great loss of material and energy which they expend in active, sustained movement, and many other ways. For them, therefore, oil, starch, and other

essences of seeds and fruits are the most suitable nutriment, and to obtain these the beak is strengthened and sharpened. The necessary crushing is done by the action of the gizzard, which is usually aided by stones or gravel. The hard, conical beak of the finches serves to crack the seeds and fruits of the garden and hedgerow; the still more massive jaws of the parrots break the hard-shelled fruits of the tropics; the twisted beak of the crossbill extracts the seeds of pine-cones. In the delicate humming-birds of South America the bill is elongated and the tongue converted into a double tube like that of insects. It is used for tapping insects and the nectaries of flowers, which thus give meat and drink to the most exquisite and airy of known beings.

This brief 'summary' of vegetarian dietary suggests the relation of food to evolution. Plants themselves have a long history, in which algæ and fungi occupy the earlier pages, lichens, liverworts, and ferns the mediæval sections, whilst gymnosperms and flowering plants bring us to modern times; and we can follow the adoption of simple plants as food by the more primitive land animals, and the assimilation of the higher plants by animals which had become more specialised. That many-limbed animals live amongst moulds and the few-limbed creatures feed delicately on fruit or nectar is no casual association, but a fact that testifies to the antiquity of the one and the novelty and high place of the other. We shall also find that as many plants chequer the monotony of their diet

by a side-dish of fly-juice, so vegetarian animals may lose their strictness and vary their menu with flesh, and only after obtaining a commanding station do their succeeding generations revert to that safe but laborious habit of grazing from which they set out.

The quest for prey : I. *The supply of food in the sea.* We speak, and rightly speak, of the heaped measure of plant life and of the dependence of animals upon the pastures so provided. But there are commonwealths in which plants shrink to an invisible factor where yet animal life abounds. The high seas and the depths of the ocean teem with animals, yet it is only in the Sargasso Sea that weeds are visible, and much below the surface they are unable to live. Lakes and broad rivers, Arctic and Antarctic lands, sandy coasts and volcanic districts, are only fringed or powdered, as it were, with plant life. Yet in all these regions animals are found, and it would only be possible for them to maintain a strictly vegetarian diet by an enormous reduction in their numbers. As a matter of experience we know that many animals are carnivorous by preference and nature. The mole would die in the richest garden mould that contained no worms, and the spider would starve in a well-kept hothouse. How this carnivorous mode of life has been attained is the problem before us.

Drifting on the waters and raining down into its depths is a motley collection of flotsam, part plant, part animal. Covering the rocks and weeds are the infusoria, sponges and barnacles, hydroids and coral

polyps, sea-squirts and bivalves, whose irrigation works are ceaselessly straining the water, filtering off and digesting the drift life. Between the two constituent kinds of filtrates, plant and animal, they do not distinguish, but swallow and digest them both. A plant, however, is more difficult to digest, as around each element of its tissues there is a tough covering such as animals only possess on their outer surface. Hence an animal once captured and torn is quickly digested, whereas a marine or aquatic plant is only dissolved with great difficulty. We are not surprised, therefore, to find that plants may live for a considerable time in the body of an animal, and, on the other hand, that animal food, being juicy and stimulating, would force the growth of those fixed creatures which attempted the diet. The hydroids, jelly-fish, and anemones have made both these discoveries, and the larger they grow the more confirmed becomes their carnivorous habit. Little by little the power of holding and then numbing moving prey was developed. Stickiness was a necessity to prevent the tissues becoming waterlogged and the cilia from flagging, and to this slimy covering these resourceful creatures added the power of poisoning their captives by the aid of nettle-cells, with which jelly-fish and anemones sharply annoy us when bathing or wading. To digest this animal food was no new or great difficulty, for the lower animals feed upon their own tissues when other food is lacking, as it often is in winter, and a jelly-fish the size of a saucer becomes,

if starved, microscopic and ultimately dissolves. Right down at the base of the animal kingdom, therefore, we find the body feeding on itself or on some other animal—in times of famine diminishing, in times of plenty growing, budding and overflowing into its children. As the jelly-fish are budded off they leave the shore, pass into deep water, and find themselves amongst less and less vegetable food. Their activity demands nourishment, and a deliberate choice of prey is made from amongst their fellows.

It is to the sea with its stress of life that we may look for one explanation of the varied food of animals. The strand itself, barren and lifeless as it appears, is full of buried minuscules, plant and animal. On this supply the larger animals depend, and in it they bury themselves. The lugworm (fig. 26, E) and heart-urchin (fig. 26, A) are but two examples out of many that eat the very strand in order to gain its hidden nutriment. Mollusc and urchin, though protected by armour and spines, are the resort of parasitic sea-worms and crabs that when young have gained a hold or an entrance into these citadels and grow to maturity on the secretions and crumbs of their host. The mussel shelters the pea-crab (fig. 15), the prickly urchin a sea-worm or a small bivalve.

These feeders on the minuscular life of the shore are in turn the prey of other animals. Scallop and oyster, seemingly so well protected by their shells and strong muscles, are the particular food of the starfish. Humping itself over the bivalve, the star-

FIG. 15.—A Mussel opened to show the Pea-Crabs (Male ♂ and Female ♀) within it. The Female is the larger of the two Sexes.—(*From specimens in the Manchester Museum.*)

fish plants its suckered feet firmly on the ground, and then applies two or more ranks of these suckers against the valves (fig. 16), straining to separate them. The oyster claps its shell together at the first touch, but after the tireless starfish has maintained an even strain for a time, the oyster from fatigue and want of oxygen opens its valves. Through the opening the starfish inserts its acid stomach, and the secretion of this falling on the oyster's muscle weakens it. The valves gape open, and the starfish at its leisure absorbs the contents.

Away from the shore great activity is employed. The maintenance of equilibrium, the pursuit of food, and the avoidance of powerful agitation imply sustained movement. Jelly-fish, cuttlefish, fish of all kinds, are in constant muscular tension. Hunger follows; the cold open sea and strong aërated water sharpen the appetite that constant exercise produces. Around these hungry swimmers is a drifting stream of wriggling, darting, whirling particles—the offspring of the shore. These enter into every mouthful of water that a fish takes to discharge over its gills, or that a jelly-fish inhales for a fresh spurt, and the choice of food is soon determined.

Fish rarely masticate their food. Their jaws, preoccupied with breathing, can only momentarily hold and bolt it; and since plants above all other aliments need grinding, they form the least desirable choice. Hence it is that the oily rowing-shrimp becomes the mackerel's *bonne bouche* and the favourite

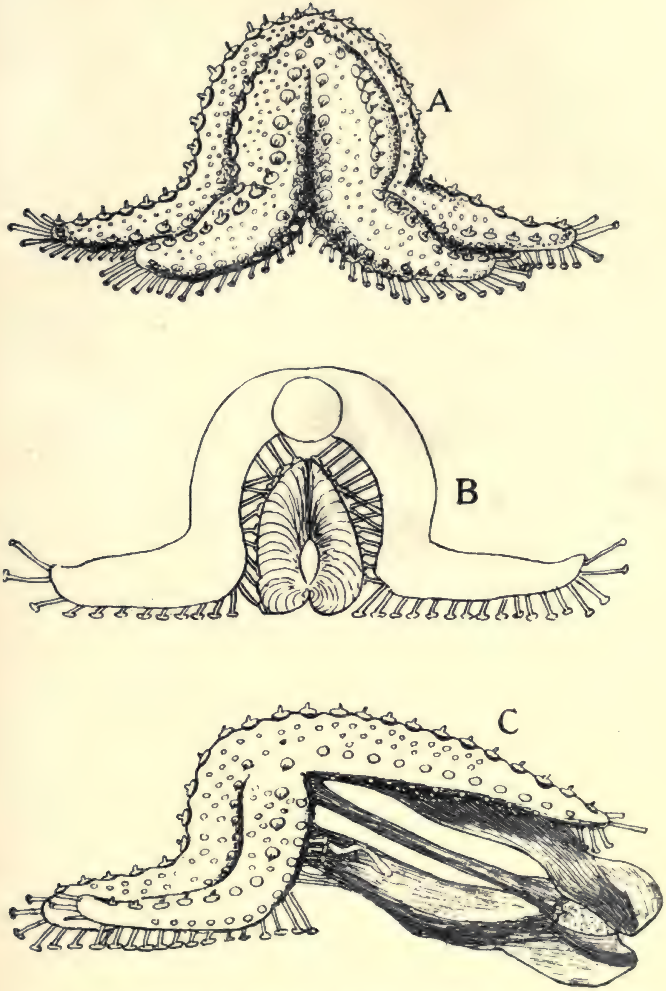

FIG. 16.—The mode in which a Starfish opens and eats an Oyster. A. The Starfish gathered over its prey. B. Section to show the position of the sucker-feet on the valves. C. The long stomach of the Starfish absorbing the Oyster through the open valves.—(*After Schemenz. Permission to use granted by Professor Henking, Berlin.*)

titbit of the herring, in pursuit of which these migratory fish travel in bands from sea to sea with an avidity that is never surfeited. In like manner, though with the help of a vast baleen sieve, the right-whales thin out the stream of minute animal life that sets from the Arctic to the temperate zone. Should the sea fail, as it does in winter, to break out into this dance of drifting life, the active swimmers retire to the bottom or deeper water, where they discover an abundance of food in the vegetarian Crustacea and molluscs, in the oily eggs of the herring and the newly hatched fry of the plaice and cod. Let but a shrimp stir a tentacle and the hungry dab seizes him. The John Dory stalks the swimming shrimp, going forward with his flat body edgewise and unseen, and at last lunging out with his sucking, extensible jaws. The dogfish, no longer sustained by nourishing herring, bolts crabs and whelks to satisfy his raging hunger.

Marine invertebrate life teaches the same conclusion. Cuttlefish, masters of marine invertebrates, are the most active swimmers it produces, and dart in vast shoals through the water, first in one direction, and then in a tangential track, forwards and backwards with equal facility. In shape and movement they resemble fish. To supply the demands for such energy the scanty algæ of the mid-ocean are inadequate and a richer diet is requisite. This the squid, as they are called, find in the herring and mackerel. They follow the migratory shoals

with an energy that sometimes sends them leaping high out of the water. Pouncing upon a fish, the squid opens a circlet of arms till then kept close like the ribs of an umbrella, and with these and the two long tentacles which can be shot out from their cases on either side of the head, it grasps its prey. Its hold is rendered secure by the suckers and hooks that stud the tips of the tentacles and the whole length of the arms. Then, bringing the fish up to the mouth and horny beak, it rasps off the flesh by the horny tongue that is the common heritage of all molluscs. So great is the strength which these fringe-finned squid obtain from their food that we have no engines quick enough to catch the larger kinds, and it is only as storm-tossed corpses that we know of monsters with arms as thick as one's thigh and suckers as big as saucers. Yet, great as they are, there is one still mightier, the epitome of the hungry life of the high seas. This is the sperm-whale, which sculls almost at destroyer rate, thrashing the water into foam. Of his seventy feet of length, thirty feet is sheer head and jaws, and with these he despatches the colossal squid ; and it is from the interior of sperm-whales that we have found out what manner of cuttlefish are roaming through the ocean unseen and unsuspected.

Sea birds also are carnivorous. Their activity, the maintenance of their bodily warmth, no less than the feeding of their young, demand more nourishment than the watery seaweeds can furnish. The year round gulls haunt the coast for any flesh diet that the

sea affords. They herald the shoals of migratory fish and the advent of their fry ; some decimate the cockle-beds. From the far north to Australia wading birds forage along the coast, and find in sand-worms, molluscs, and sand-hoppers a never-failing food-supply. On our rocky coasts, from April to July, the puffin, the guillemot, and other spring migrants of the sea

FIG. 17.—The Black-headed Gull, Nest, and Young.
(*From specimens in the Manchester Museum.*)

have made the rocks musical with their chorus, fishing the day through, and disappearing in late summer as mysteriously as they came. With autumn the stream of southward-going shore birds take their place, and in the hardest winter flocks more dense than those of spring cover the sand flats, and find abundant nourishment on the inexhaustible shore.

The quest for prey: II. *Adaptations of land animals.*—On land the problem of maintenance is more complex. The extent of pasture is greatly increased; plant sheddings and mould correspondingly denser. The supply of vegetal life is beyond computation, and if animals dominate the sea, plants characterise the land.

On the other hand, there are no fixed encrusting animals—no barnacles, sponges, zoophytes or bivalves—whose families can swell the drift life of air. Food must be sought mainly on the ground, and has to be actively gathered by movement in which the weight as well as the resistance of the body has to be overcome. This added strain increases the need for nourishment which the pursuit of food seeks to satisfy, and as the climate is no longer one of great uniformity, such as that of the sea or large inland waters, the hardships of heat and cold aggravate those of hunger. Moreover, plant-life also protects itself by thick coatings against the inclement effects of drought and frost, of excessive moisture and dryness. The result of this is to render such food very difficult of mastication.

How widespread this difficulty has been and still remains we realise but slowly. We think with facility of plants as food for animals, and we overlook the fact that whilst such is the rule, exceptions meet us on every hand. The abundant mosses are scarcely touched by a single animal, though no form of shelter is more popular than their crevices. The ferns uncoil their fronds in undiminished numbers every summer,

and when autumn comes the roll-call is complete, for there is no plant more secure from animal interference. The lycopods, the mare's tail, and the vast host which form the vascular cryptogams are passed by and avoided. But when we come to the primitive seed-bearing plants—the pines, the cycads—we find primitive insects, a sawfly, a few wood-borers, squirrels, and a few birds capable of obtaining nourishment from them. It is mainly the flowering plants at the top and the fungi at the bottom of the plant kingdom which constitute the supplies of vegetable food of which animals can avail themselves. And neither by birth nor adaptation have all land animals the taste or the capacity for the requisite work of getting at that nourishment and assimilating it. How an alternative diet—that of flesh—has been maintained or adopted by so many terrestrial animals we may now consider.

By three paths land animals have become carnivorous. We have seen that the primitive air-breathing animals—*e.g.*, *Orchesella* (fig. 12)—fed on moulds and lichens, which are found everywhere. From moulds, and especially from fungi, it is but a short step to a flesh diet. In the second place, we saw that piercing and sucking organs were developed as the higher insects discovered the sap or honey of flowering plants, and found that for flight such a diet was eminently suitable. For such creatures the transition to parasitism on either plant or animal, or to the habit of sucking the juices of active prey, was an easy one.

Lastly, in the higher animals the appetite for a flesh diet acquired in the sea persists after the change to fresh water, and thence to land, has been accomplished, and it is only as the result of a happy and complex combination—good grinders and strong digestion—that the power of assimilating sufficient vegetable food has been acquired by the Herbivora. We may now consider how these habits have conduced to the welfare of land animals.

Insects show well the strain of life. The most primitive are feeders on moulds and lichens ; the most degraded are parasites—fixed sucking animals ; the most highly organised are pre-eminently active sucking creatures.

As the tiger is a lord among mammals, so is the tiger-beetle among the huge tribe which his name heads ; and no more ferocious, active, or bloodthirsty beetle exists. From his youth up the two curved jaws that signalise his ferocity are in constant employ in attack, as he beats up and down hot roads and sandy commons, quartering the ground in arrowy darts from fly to fly.

The dragon-fly is an equally dominant member of its tribe, and in brilliancy, power of flight, and rapacity is perhaps supreme amongst insects. Supported throughout life on a flesh diet, it represents to many another fly the long arm of circumstance. The dragon-fly attacks its prey with equal celerity on the ground or in the air, and, as it possesses both excellent sight and flexible lips and a strong pair of jaws, it is

able to secure the prey by their aid, and then holds it in the basket formed by its feet. Again, the Emperor butterfly and hawk-moth are severally at the head of these two groups, and are fine examples of insects adapted for sucking flowers; and to satisfy its thirst the Emperor descends from the tree-top for a puddle or some dead creature. The mantis is the most elaborate of the class to which it belongs, and though maintaining a still attitude, waits but for a fly to alight near to display the ferocity and blood-sucking instinct that animates it. Even the grasshoppers, that haunt sandhills and match the colour of their surroundings so closely, feed upon the flies that perch unsuspectingly near them. The true flies specialise in sucking, and for the delicate probe that can pierce a tough land plant the hide of a beast is no impenetrable armour. Drawn by the sense of smell from plants to fungi, from fungi to dead animals, and thence to living ones, various families of flies have discovered the stimulant of blood. The mother-fly in particular, having but a summer to work in, discovers the greater fertility which such a diet ensures and the greater number of broods which may be reared when warm-blooded animals are drawn upon for nourishment. Ants, bees, and wasps, the highest members of that vast class, the Hymenoptera, employ the most varied methods for obtaining nutritive fluids. Plant or animal juices in a concentrated form are their favourite nourishment. Ants milk their cows—the aphides—from whose bodies flows the nectar or honey-

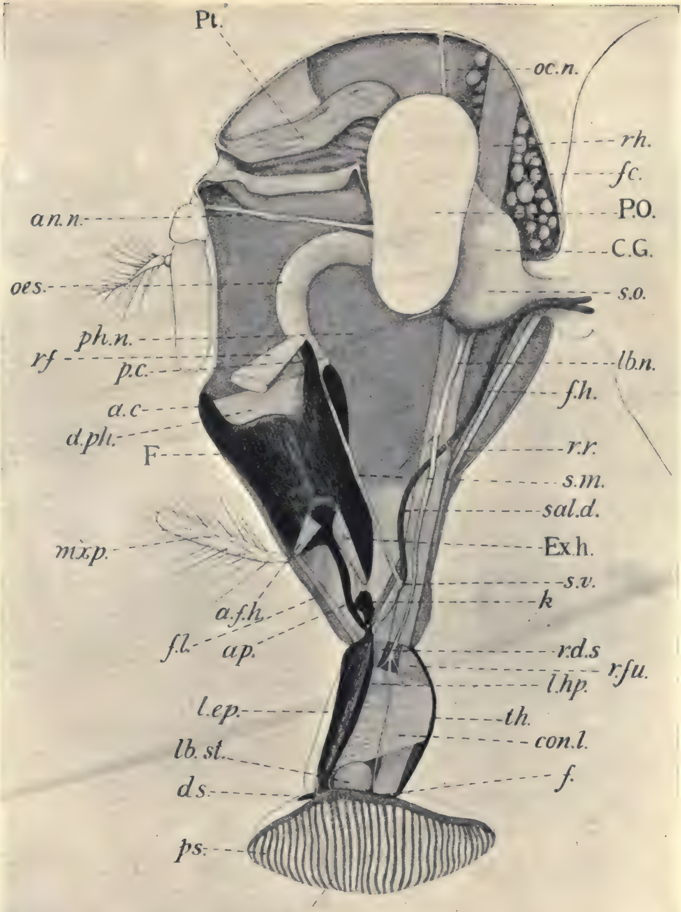

FIG. 18.—Tongue of House-fly. Left side of head removed to show internal structure. The empty space is filled with air-sacs not shown in the figure.—(*With C. Gordon Hewitt's permission, The University, Manchester.*)

Pt., eversible 'frontal sac'; *f.c.*, fat-cells; *C.G.*, *s.o.*, brain; *P.O.*, portion of brain supplying nerves to compound eyes; ***an.n.***, *oc.n.*, nerves to antennæ and simple eyes; ***ph.n.***, ***lb.n.***, nerves to suction pump and proboscis; *r.h.*, *f.h.*, *r.r.*, *r.f.*, muscles for retraction (or withdrawal) of proboscis; *r.fu.*, *r.ds.*, *con.l.*, muscles opening mouth and controlling the flow of fluid along the 'throat'; *af.h.*, *Ex.h.*, muscles controlling the bending and unbending of the proboscis; ***ap.***, rod concerned in the same process; ***F.***, sheath of 'suction pump,' with its processes *a.c.*, *p.c.*; *d.pn.*, muscles working 'suction pump'; *k*, sheath keeping open beginning of 'throat'; *oes.*, 'throat'; ***l.ep.***, upper lip; *th.*, lower lip, also formed by part of *l.hp.*, *d.s.*, and *f*, skeletal structures of the oral lobes, one of which is shown; *ps.*, channels, and *gp.*, 'taste pits,' of the oral lobe; *lp.sr.*, one of the two saliva glands of the oral lobes; *sal.a.*, duct of large saliva gland, with ts valve, *s.v.*, and muscles, *s.m.*, controlling the same; ***mxp.***, maxillary palp.

dew which they laboriously secrete. Bees so much prefer the dew to the trouble of securing honey that in some years hives are a failure. Wasps both sop up fruit juice and devour other insects, killing them with a sting and storing them in their burrows.

The higher Arachnids, the spiders and scorpions, contrast with their degenerate allies, the mites and ticks, by their large brain and complex structure, which bear witness to their high place among invertebrates; and this conclusion is borne out by their nourishment and the means they adopt in obtaining it. If to feed by sucking the juices of a captured organism is a sign of superiority, spiders and scorpions are sure of a high place, for their methods show exquisite adaptation to secure this end.

So exclusively is the whole class of Arachnids a race of sucking animals, that it has lost the jaws which all but the most modified insects retain. In their place these animals possess a pair of small sharp nippers, within which lies a poison-bag, so that every nip injects some venom into the prey. The second pair of limbs is usually leg-like, but in spiders it so far differs from the four remaining pairs of legs that its base is expanded to form a jaw-like process which helps to hold, though not to chew, the food. In the scorpion the second limbs form a pair of claws, and in the mites a sheath, within which the first pair or piercing organs can be held. The act of sucking is performed not through a proboscis as in insects; the tiny mouth is applied direct to a wound in the prey,

and its juices are sucked by the alternate expansion and contraction of the throat. By this means mites, red spiders, and ticks devastate our currant-bushes and hop-plantations, destroy cheese, books, and furniture, become blood-suckers of man and most terrestrial animals, and in tropical countries are one of the

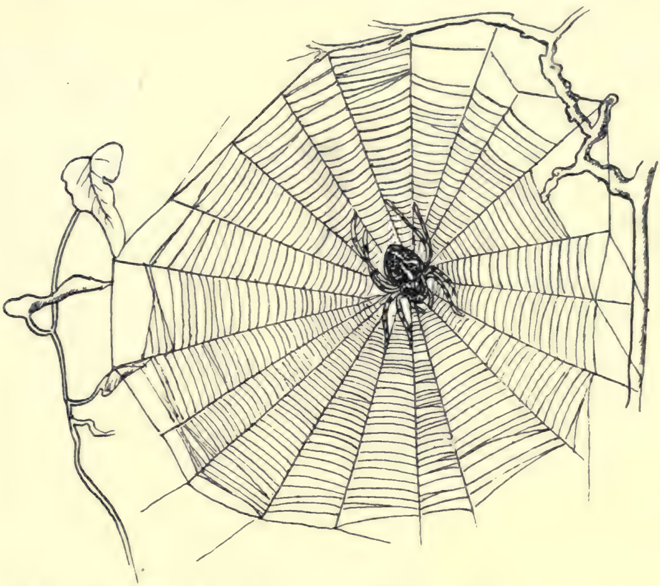

FIG. 19.—Wheel-web of the Garden Spider.—(*After Blanchard.*)

means whereby such diseases as relapsing fever are transmitted. Spiders are one of the dominant races of animals, and in hunting instincts excel all others. Their power of constructing webs, underground traps, and even sub-aquatic snares, is well known, but the variety of traps and the ways in which these snares

are formed and concealed and managed are scarcely appreciated.

The web of the garden spider is essentially the work of the mother. It is she who constructs it, she who watches it and feels the pulse of its lines from her hiding-place. When a mote is blown into the web it is the mother who sallies forth to remove it. When a fly is entangled it is she who emerges and, enveloping the struggling prey with more silk, retires to enjoy the feast. Her mate is but a casual incident, whose presence is tolerated for a time, but soon forgotten in the stress of capture and the care of young. In times of unusual hunger he may even be devoured.

The web of spiders is unique. There is but one other example of a net stretched out to catch prey, and that is the seine-net of a caddis-fly larva, into which river-borne flotsam drifts and is devoured by the watcher (*see* p. 237). But spiders are the only animals which have found a means of intercepting the humming life of the air.

The silk of which it is spun is the finest and strongest natural product. In itself it is no new thing. A gum which, when drawn out to a fine thread forms silk, is produced by a gland opening into the mouth of most caterpillars, of which the silkworm is but one. That which distinguishes a spider's silk is its variety. One kind of silk is used for the outer framework and the radial lines, a second for the circular lines, a third for the enwrapping of prey, and a fourth

for the construction of the cocoon. Each sort of silk is made by a collection of glands that open near the end of the body by a little spout called the spinneret. The lines of a geometrical web are laid down in the following way. First an outline is drawn; to form this the female shoots out the requisite thread, fastens it to some support, carries it in her hind feet, streaming out of the spinneret and

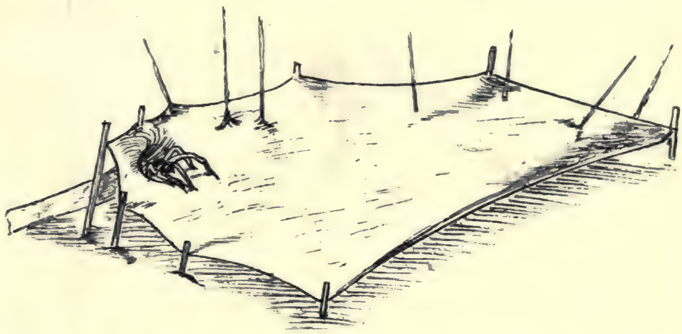

FIG. 20.—Web and Nest of *Agelena*, spread on grass.—(*'Riverside Natural History,' by permission of Messrs. Houghton, Mifflin & Co., Boston, U.S.A.*)

hardening as it emerges. Presently it touches a twig or leaf, to which the spider fastens it and stretches it tight with her claws. Then, letting herself straight down and drawing out the silk behind her, she forms one of the vertical sides. Afterwards the other sides are completed in the same fashion. Across this framework the spider draws a thread, fastens it with her claws, and tightens it, so as to form the diagonals. From the centre of this she travels to another point of the

framework and draws the first radius, up which she travels to the centre again, and by repetition of the process the spokes of the wheel-shaped web are run across from the centre to the circumference. Once

FIG. 21.—Nest of *Agelena* made by the young on surface of furze.
(*From a specimen in the Manchester Museum.*)

more running to the centre, the spider constructs a temporary spiral, the turns of which are looser as she travels outwards. Finally the finished spiral lines are spun of a second store of glands. These are more sticky than the rest, and serve, of course, to entangle the

prey. The temporary line or scaffolding is then cut away.

The whole process of making a web takes about half an hour, and after finishing it the spider retires. Her object now is to keep in touch with the movements of the web. This she does through her feet, which are sensitive to the slightest vibration, and her complex nervous system probably enables her to interpret each kind of vibration as signifying a definite disturbance. In response to the tug she feels her action takes several forms. It may be that a gust of wind will immediately destroy the web, or that a large insect may blunder into it. But in the event of calm weather and no accidents the advent of prey may be, and no doubt is, eagerly and confidently expected. Should a fly become entangled, the spider is at once aware, and adapts her behaviour accordingly. She evolves her stickiest silk, seizes the fly, and, running round and round her prey, envelops it somewhat as she spun the circular web lines. She now plunges her poison-organs into the fly and proceeds to suck its juices, thereafter casting out the skin and smoothing

FIG. 22.—Nest of Cave Spider (*Meta menardi*), to show the way in which the eggs are surrounded by silk and supported by a stalk.—(*From a specimen in the Manchester Museum.*)

down the web. A butterfly is similarly treated ; but a wasp is sometimes allowed to escape with the utmost celerity by biting through the lines that bind it.

The variety of webs is great. There is the funnel-shaped web, so common under stones and among old walls, from which at the least touch out rushes the artificer. This funnel plays upon the weakness which so many insects have for investigating dark corners and for seeing where tracks lead to. Other spiders choose stations over water where gnats and midges abound. The surface of meadows and heaths are covered by flat webs, which in the frost of an early autumn morning form an almost continuous gauzy covering (fig. 21).

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CHAPTER VI

THE BREATH OF LIFE

It is a faithful saying that we do not live on food alone. Life is a fire, now slow, now fierce, and therefore needs air as well as fuel. Changefulness is of the very essence of being, and all our rest is but hidden activity. Growth, movement, development—all the expenditure of force, which are the shows of life—involve transformation of our substance. We burn that others may have light; and just as the sparks fly upward under a fire's breath, so we and all beings need a fan if the fires of life are to become active. Food is but the laid fuel; oxygen, that which fans it. The fire was lighted long ago. The twinkling flames hidden in thought, patent in conduct, have come from the vestal lights of other generations. Every moment of restful or restless activity they maintain the transformation of our bodies. We are renewed year by year, and to make way for the new being the old is slowly burnt away. We breathe out coal-gas, we radiate warmth, our muscles work by innate explosion. For every breakdown which is the necessary preface to this constant renewal, oxygen is essential. We rise on our dead selves only by their combustion. But so

generous and ungrudging is the renewal, so serenely is the new man made, that we forget that all balance is complex adjustment and all progress hardly won. We mark, not the loss that energy entails, but its sustained and transforming activity. Artists by nature, we rightly overlook the pains of effort. But if we are to comprehend the working of that mysterious life the activities of which arrest us, then we must be possessed by the conception of the downfall which precedes every uplifting in the transformation of living tissues. The more thorough the burning, the more complete will be the reconstruction, and health is as dependent on the one as on the other. We rise Phœnix-like out of our own ashes. As we obtain explosion by confining the area and increasing the rate of expanding activity, so a muscle gives out in one convulsive movement a force which at other times is spent in gentle and repeated efforts. But whether gentle or explosive, muscular action is only sustained by oxygen, and the more vigorous the effort, the greater the demand.

As for muscles, so for other tissues. Our very bones are constantly being renewed. Where the seeming waste is greatest, there the new growth is most active; and should this new growth be no reproduction of the preceding part, but an addition or new development, then it is subjected still more fiercely to the alternate tides of waste and repair. Breakdown by oxygenation, reconstruction by feeding, is the rule by which we live and move and work out our being.

This strange instability, as of a fountain summit or of a flame, is of the very essence of life and creates the need for oxygen as well as the need for control. If the demand or supply is small, the life will be inactive ; if ample, vivacious ; if greater still, feverish. At one end of life's scale we have the latent life of seeds, the suspended animation of winter sleepers ; at the other the consummation of a Shelley. Between the two we have the periodic sleep and growth of plants, the gradual rise of animal activity in water, on land, and in the air, and the final achievement of permanent activity of body and mind.

Life, however, outruns our metaphors. In variety of working, inwardness, and thrift it transcends our figure of flame. Biological activity is not exhausted by combustion. Muscle and nerve are most complex tissues, and their inward changes are correspondingly complex. Movement, whether of plant or animal, involves a change of its electric tension which may be too delicate for perception unless studied by a sensitive electrometer, or so powerful (as in the torpedo or electric eel) as to disable us. Nervous activity, again, is akin to electric action. Even respiration is not always the slow combustion we have described. A molecular as well as a mass exchange of gases is known in plants and animals. Leavening prepares for life.

The inwardness no less than the variety of biological action contrasts with our simple figure. A fire is an affair of surface changes. Living things, on the other hand, burn from within outwards. Fuel burns only

in free oxygen. Plants and lowly animals possess a disruptive faculty, by which they can in the absence of free oxygen break up their store of carbonic gas and set it free. From reserves in seed or muscle fresh energy is obtained by this analytic action. Moreover, in ordinary muscle-breathing the oxygen in the blood is not directly used by the tissue, but is first stored, controlled, and delivered subtly to the muscle, under the pressure of that inward, invisible governor that converts the breath of air into the breath of life.

Nor, again, is the contrast of economy in vital actions with the waste of fuel a less conspicuous feature of their work than variety or inwardness. The best coal-motors are wasteful, and give out in the desired form of work but one-eighth to one-ninth of the energy imparted, the rest escaping by conduction, incomplete combustion, and other wasteful outlets. Beings are rather more productive and less wasteful. A man given 0·44 kilos of food, representing a million units of energy, gives out in a day, work estimated at one-fifth to one-sixth of this. This economy, unequalled in other carbon-combustions, is due to the central and peripheral control of the nervous system playing upon the fitful external supply, and is signalised in our constant temperature, equable pulse, and regular breathing.

The quest for oxygen : respiration and evolution.—Water contains air, as we see by the bubbles that rise on heating ; but the amount of oxygen is a mere fraction of that contained in an equal volume of the

atmosphere. There is at least twenty times as much oxygen in a bottle of air as in the same quantity of fresh or salt water. When we consider this, then the fact that all the higher forms of life, plant and animal, are aërial and the lower mainly aquatic becomes more intelligible. The more complex frame of the advanced classes of life demands more oxygen than that of the simple, both on account of the speedier rate at which their tissues disintegrate and re-form, and also on account of the more rapid and laborious work that their movements imply. The greater size as well as complexity to which land plants and animals attain is another reason for their more active respiration. The spacious air and abounding waters provide an unlimited store of the requisite oxygen. Unlike the search for food, which is a quest beset with difficulty and uncertainty, the breath of life is around all that live upon the earth and bounteous beyond computation. At the surface of the earth, or that of the hills, its richness is greatest, and as we descend to the waters its bounty diminishes. Above and below the surface the amount of oxygen varies. If we climb beyond the snow-line this change causes mountain-sickness ; if we enter a cave our lights burn low. As with the surface of the earth so with the surface waters. The upper strata are rich in oxygen from wave-movement and the imprisoned air of the foam ; and this bounty is reflected in the teeming life and comparatively high development of its fauna ; below in the stillness there is poverty of oxygen, only matched by the cave

region; and yet where oxygen has diffused, the darkness is peopled by hungry strays and waifs. Whether in the earth or in the waters the highest forms of each order come to the surface, the lowest are submerged; and emergence or submergence corresponds to plenty or poverty of oxygen.

This air we breathe has only been reached by epochs of struggle and new departures. The possession of the earth is hardly won. Before the nimble air gave strength and impetus to the conquerors they had to pass the marsh and shore on their landward way. Plants and animals alike have striven for the face of the waters, for the beach, for the marshes, and finally for the air. Man himself carries in his ears an unmistakable sign of his gill-breathing, watery past, and of the depths he has left behind him. Evolution follows the successful quest for oxygen, and therefore earth has been peopled by the highest communities. The ancient stocks are scattered, some keeping to the beach, some lurking in dens and caves, or, as parasites and messmates, hiding away, degenerate and prolific; some, such as whales, returning to the waters, where they maintain an unfair supremacy over the unemancipated fish. Refugees from the shore and from the surface of the water retire to the depths, and there, at oases in the general desolation, hang out their phosphorescent signal lights.

Evolution of the respiratory methods of animals.—The drama needs elaboration. Its climax—the possession of lungs and of a good circulation—comes last in the

history of every group that has attained supremacy. The earlier acts are done under water.

The simplest animals, so-called Protozoa, are all characteristically aquatic. They either live freely in water, or in a water-bath which some animal or plant provides for them. Furnished with oars or 'cilia' they pursue and engulf their prey; or, if stationary, draw in liquid instead of being drawn through it. Thus both inside and outside they are bathed by constantly changing water; and from one or both of these sources they extract the minimal quantity of oxygen which is dissolved in such water, and it suffices them. By its aid, movement is maintained, the food broken down, and the living substance, after rebuilding and replenishing itself out of that food, is disintegrated as the first step in another cycle of life. Neither lungs nor gills are distinguishable. There is no blood to carry oxygen or to remove carbonic acid. The protozoon is a gill and heart in effect, though not in fact. It does with its seemingly simple tools all that taxes the complicated structure of a higher animal to accomplish in breathing, namely, to abstract oxygen from the air dissolved in the water, to convey that oxygen whither it is needed, to use the store without exhausting it, and after use to carry away the ashes and smoke of the fire.

Sponges, corals, and anemones are animals whose bodies are channelled out for the passage of water. These creatures irrigate their bodies by a stream that passes in through one or more openings, then through

a sieve on which the food is collected, and finally out again by the same or a different path. This constant irrigation carries water within the reach of the various tissues, so that without any blood-vessels they are yet able to derive oxygen from the stream, and to empty into it the débris of that slow combustion that water cannot quench. This removal of the ashes of combustion is largely assisted by the activity of minute plants that infect and colour the coral and anemone.

But growth, as well as breathing, depends on the supply of oxygen, and as these inert animals grow freely instead of moving actively, they utilise the bounty of the surf for the spread of their colonies. Sponges cover the rocks of our coasts, and each of these, if cut into a hundred pieces, will grow into a hundred sponges as large as the first. Anemones coat our shores and will propagate, as well as sponges, by cuttings. Corals form barriers and reefs miles in extent, and build up island and mountain by the growth of succeeding generations. Nor is their life a short one. A sea-anemone lives twenty-five years, and may live to over fifty, and corals are of equal longevity.

This long-continued growth implies a rich supply of oxygen; and in two different ways these fixed animals gain a better supply than that which still water contains. First they colonise the region of surf. Sea-water when shaken up with air increases the amount of its oxygen many fold, and from the surface down to a depth of some twenty feet the amount

is considerably greater than in the stiller depths. The influence of this fact upon the growth of sea-animals is continually brought home to us. Life and foam are old associates. The region of greatest animal growth is just where the water is most sparkling. So long as the swell is not so heavy as to tear and grind all that is not solid rock it will foster growth. 'Full fathom five' is the depth down to which most corals flourish, sponges cover the rocks, and anemones afforest the coast. Where the tide runs strongest, there will be the richest growth, and that not only because it brings new food with every flood, but because it carries fresh supplies of oxygen.

The second method that these long-shore encrusting animals adopt to gain more oxygen is to increase their capacity for holding it. The red colour of our blood has exactly that meaning, and as its tone waxes and wanes so does our energy; and for this reason, that the red pigment has a strong affinity for oxygen, binding it to itself, and in so doing deepening in tone. When rich in oxygen its colour is bright and vitality great; when poor in oxygen the colour fades and the body grows faint. The sponges and their allies give us a first hint as to the origin of these respiratory pigments, for we find them of the most varied tints, but chiefly red, yellow, and green. These colours which, if we ever notice, we think of merely as decorative effects, possess a value to these animals which decides not life—for these tough primeval beings hold to life at many points and defy a sudden

taking off—but, what is of greater significance, their increased vitality and productiveness. Needing but little oxygen for their own consumption, they are able to utilise any small surplus with great advantage, as in growth; and it is probably this help that colour gives them. These reds and yellows, more than the uncoloured parts, on this view, seize the passing oxygen, store and then dispense it to the tissues.

The respiratory adaptations of Crustacea and Molluscs.—Among higher and more active creatures the demand for oxygen is more insistent, and the irrigation system becomes limited to particular regions, over which a stream of water flows in and out. These regions—the gills—are thin-walled folds of skin, within which there flows a fluid which is no longer water, but blood, thicker than water. Its channels lead to and away from the gills, and the streams that fill them course past the gill-walls, as they circulate. The sea-worms bear a tuft of gill-plumes on every segment, and each of the simpler sea-shrimps and pond-shrimps carries a plume on its thigh. The very effort of movement shakes the gill, brings it to fresh bodies of water, and stimulates the circulation. The movements of such creatures help to create the supply of oxygen which they demand, and if food were easy to come at and enemies few, there might be no need for more elaboration than gill-plumes and gill-circulation. Such, however, is notoriously not the case, and we find in each kingdom—that of the worm and that of the

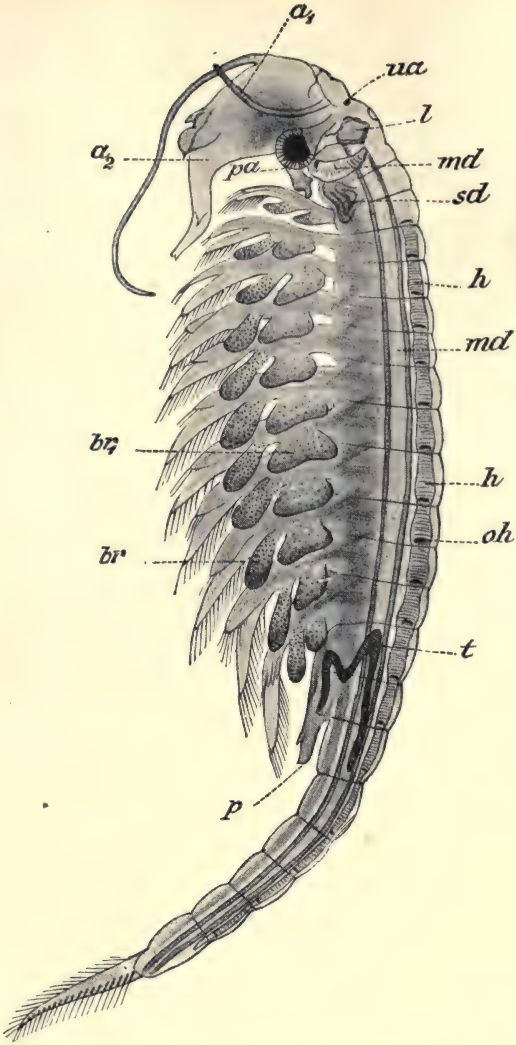

FIG. 23.—Brine-Shrimp (*Branchipus*), a primitive Crustacean found in salterns in the south of England. The gills are fixed on the bases of the swimming-legs.—(*From Lang's 'Comparative Anatomy.'*) × 20.

a_1, first antennæ; a_2, the large second antennæ; *ua*, unpaired eye; *l*, liver; *md*, mandible; *sd*, kidney; *h*, heart; *oh*, openings of heart; *p*, male organ; *br*, gills.

shrimp—a variety of breathing devices adequate to the different demands of its members.

To meet these varied exigencies two methods have been elaborated with great detail. First, the construction of a channel along which the oxygen-holding water is made to flow, and, second, an increase in the oxygen-holding power of the blood.

The first of these methods is the secret of the greater advance that the shrimp family has made over that of the worm, and it is also the motive underlying the formation of the shells of the molluscs. The buckler of a shrimp, lobster, or crab, the valves of a mussel, are tubes confining the respiratory current to a comparatively narrow area in which the gills lie, and thereby increasing the rate at which the water can be drawn over them. The second of these methods is largely effected by pigment. Our blood we know needs iron to keep it healthy, and it is a fact that gives us new affinity with lower animals that in them also the same ferruginous red blood is found. It occurs in those which have to live where oxygen is scarce or in parts of the body where muscular action is most sustained. Elsewhere we find a copper salt taking the place of the iron one, giving with oxygen not a red but a blue tint, and possessing only a quarter of the oxygen-holding power that belongs to hæmoglobin, its iron relative. Finally, in the less exigent forms the blood is hardly more than a stream of watery albumen.

The working of the first method is easily tested. If some powdered carmine or indian ink is placed

just behind the last leg of a crayfish at rest in a dish of water, a series of puffs of the colouring matter will

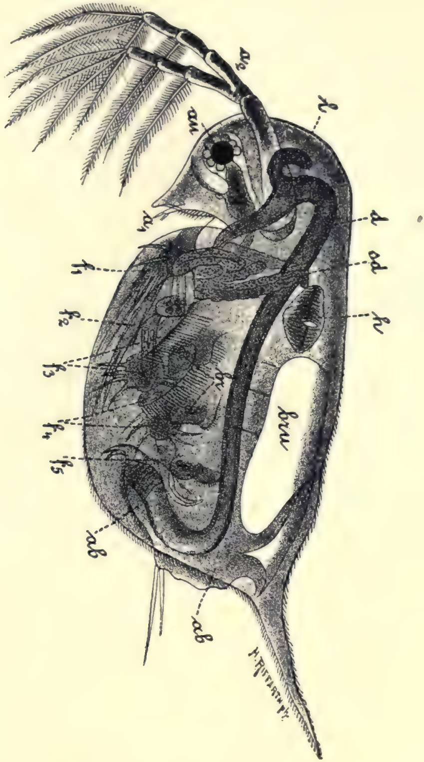

FIG. 24.—*Daphnia*, an abundant freshwater Crustacean ; the body is enclosed in a carapace ; the limbs, less numerous than those of the Brine-shrimp, carry gills.—(*From Lang's 'Comparative Anatomy.'*) × 50.

a_1, first antennæ ; a_2, second (rowing) antennæ ; *ab*, abdomen ; *au*, eye ; *br*, branchial sac ; *bru*, brood cavity ; *d*, intestine ; f_1 to f_5, trunk feet ; *g*, brain ; *h*, heart ; *l*, liver ; *sd*, shell gland.

issue in a few moments from beneath the eyes of the creature; and if we seize it and examine the under

surface of the head, a rapid movement may be observed at the sides of the mouth, indicating the position of the bailer ; the gills are, in fact, enclosed in such a way that the space around them is converted into a tube, open in front and behind.

In a burrowing animal, however, such a method entails the danger of sucking up débris and choking

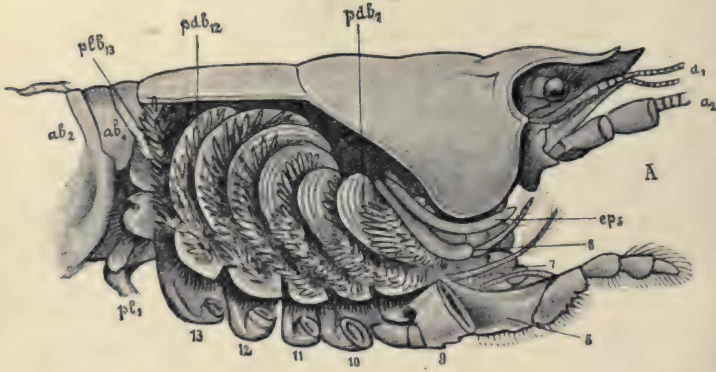

FIG. 25.—Head and thorax of Crayfish, to show the gills and the bailer, ep_5. (*From Lang's 'Comparative Anatomy.'*)

a_1, a_2, antennæ ; ab_1, ab_2, abdominal segments ; plb_{13}, pdb_{12}, pdb_7, gills ; pl_1, first swimmeret ; 5–13, thoracic appendages.

the gills. Accordingly we find among burrowing crabs a great variety of devices which, while permitting them to escape their numerous foes—the larger fish—allows them to maintain an in- and outgoing current without blocking the gills. The common crab, which sinks up to the eyes in soft sand at the slightest warning, has a reversible gill-current. In general, it draws water through an opening at the

base of the foot-jaws and exhales it beneath the eyes. When sunk in sand it performs the opposite movement, and drives the water out at the opening through which it had previously inhaled it. The masked crab, which burrows deeply into the sand, possesses a special breathing tube, through which it can inhale fresh draughts of water. Its antennæ are brought together by interlocking hairs, so producing the tube, and the water then passes backward over the gills and out amongst the feet (fig. 19, F).

The burrowing bivalves—razor-shells, rainbow-shells, cockles, and the like—provide themselves with a breathing siphon. To escape their numerous enemies and to evade the digging action of the sea, that threatens to evict and pulverise them, they possess a flattened shell, which easily passes through the sand as the spade-like foot hauls them into the burrow. But without some means of breathing surface-water these animals would be speedily choked, and their delicate gills lacerated by the flinty particles around them. Accordingly we find they have developed a long, bent siphon, the original fringe of their double tube drawn out to twice the length of the animal. Through this double tube the bivalves can reach up to the surface-water and tap a supply unmixed with sand. The current runs down one tube, bathes the delicate plate-like gills, and after passing through the body rises again to the surface, where, to avoid contaminating the supply, the outlet tube is turned away. When alarmed the animal withdraws its tubes into the shell, in which

they lie till the disturbance has passed away. Their presence has impressed a line inside the shell, so that in place of a mark running parallel with its

FIG. 26.—A group of Burrowing Animals from a sandy shore. A. The Heart-urchin, showing its tube feet gathering food. B. A Bivalve (*Scrobicularia*), showing the inlet (*b*) for water and food and the outlet (*a*). C. The Cockle, showing inhalent and exhalent tubes. D. The Mud-clam (*Mya*), showing the same. E. The Lugworm. F. The Masked Crab, whose antennæ form the inhalent tube.—(B–D *from Messrs. Meyer and Möbius*; A, *after Graber*; E, F, *original.*)

edge, the border of the contracted siphons forms a bay, and by it the bivalves with long siphons may be distinguished when we have only the shell to guide us.

The univalves, or snails, have more varied breathing organs. The majority of sea-snails carry a tube, trunk-like, in front of their head, as they creep over the shallows at low tide, and by this trunk they inhale water which, after travelling over the gill hid within the shell, goes out by a slit near the base of the trunk. To support the trunk the snail-shell has a groove or spout, and by it the presence of the breathing-tube may be known even from the shell alone. Other sea-snails have no such canal, but are, as it were, snub-nosed, the nostrils being separated into an in-letting and an out-letting one. A few, such as the ear-shell and the key-hole limpets, have a slit, a row of holes, or a single hole, through which the water makes its escape after bathing the gills.

Cuttlefish, squid, and nautilus have a short funnel, or escape pipe, for the same purpose, and in them the effort of breathing is convulsive; the whole body shakes with the effort and twists its gaping orifices as it unceasingly sucks in and transmits the gulps of water that flood its gills. The size, activity, and growth of these fierce creatures demand larger quantities of oxygen than are needed by other snails, and as the blood courses through their gills, it changes from a colourless to a blue fluid, a sign of the presence of that coppery blood-pigment which holds oxygen

with a capacity only exceeded by the red iron pigment which we possess.

In each of these tribes—those of the worm and of the shrimp and snail—we find many air-breathers. There are earthworms and land leeches, land crabs and wood lice, land snails and land slugs. That these are descended from aquatic ancestors is shown in their dependence upon moisture. A worm shrivels by heat and is killed by frost. Its delicate netted skin is a gill that can withstand neither extremity of climate to which aërial life exposes it. Hence the tropics with their damp undergrowth, and the deeper soil with its more tenacious moisture, are the chief resorts of these adaptive air-breathers, for it is in such places that perennial damp is secured.

The breathing of vertebrates. Gill-, lung-, and voice-production.—Fish differ from all animals except the zoophytes in their mode of breathing. By a succession of swallowing movements that suffer little interruption, a fish fills its mouth with water, then closes it tightly, and by compressing its throat and gullet drives the water out through its gill-slits. The margins of the slits are converted into tasselled fringes, and the muscles used in swallowing are so arranged as alternately to open and shut these side exits. The gills of a fish consist of these bundles of red tassels mounted on hoops. Each thread of the tassel contains a V-shaped blood-vessel, one limb of which comes from the heart, whilst the other goes to the body. The red colour is evidence that only a thin skin inter-

venes between the blood in the gills and the water which bathes them in a series of successive outgoing spurts. Through this transparent covering the oxygen of the water diffuses into the blood, which, thus invigorated, is carried to the various organs of the body.

Where the activity of the organs is great the storage of needful oxygen is increased by the development of a red pigment capable of forming a reserve fund, upon which the muscles may draw for the increasing work that is demanded by the ceaseless adjustment of the body and by the rapid, powerful strokes required for pursuit, escape, or migration. The pink colour of salmon-trout and the red of the salmon and of the tunny are stores of this kind.

This constant irrigation of the gills has brought fish into intimate touch with the qualities of water. The gradual drying of watercourses and ponds in summer, or the fouling of water by the decay of vegetation, reduces the amount of available oxygen, and to avoid the threatening suffocation many fish have adopted the plan of swallowing not water only, but air as well. The common loach rises to the surface to gulp a mouthful of air. The mudfish of Africa and of America does the same. The advantage of such a plan is patent. When the water is pure and abundant, aërial oxygen is a luxury, but when, in dry weather, the stream becomes a few isolated warm pools, which decaying weeds are rendering each day less fit for breathing, then those fish which can

breathe air are able to hold out longer than their submerged fellows, and, should the next rain be too long delayed, they will be first to meet the spate and to secure the new supplies of food that the flood carries.

In order to store the air which gives them such advantage the throat of fish is puckered up into pouches; some of these are quite shallow pockets, some are long tubes running down the body. In virtue of this supply the climbing perch makes excursions overland before the dew is off the grass, and the mudfish, which tenants every sheet of water in equatorial Africa, passes through the driest season with impunity, rolled up and sleeping.

The demand for storage of gases is so insistent that we find it obeyed by almost all fish, even in those which breathe solely under water. In them the storing organ is a tube lying under the backbone and opening into the throat during the first part or the whole of life. Into this chamber gas is exhaled from the blood. In marine fish oxygen is chiefly stored; in freshwater fish nitrogen preponderates. But these gas chambers, which originally no doubt served as reservoirs of respirable gas, have lost their primary function, as, indeed, the neutral nitrogen implies, and become transformed in ordinary fish into bladders, which determine their specific gravity by the alterably greater or less quantity of their contents. Thus they have entered into the problem of movement, and, by tending to lighten the fish's back and upset its equilibrium, have led to far-reaching demands upon

the fins and the muscular control of balance. Finally, in a few catfish the gas chamber becomes connected to the ear by a chain of little bones, in virtue of which the perception of vibrations in the water is notably enhanced.

From some such appendages of the pharynx our lungs are derived. Fish of different orders have independently converted an outgrowth used at first for temporary air-storage into a sac, round the walls of which blood could be re-oxygenated and purified of its carbon dioxide. The opening of this virtual lung is even converted, in some fish, into a glottis or voice-organ analogous to our own larynx ; and in the so-called salmon (*Ceratodus*) of Queensland, once wide spread over the northern hemisphere, the organ may be spoken of as a pair of lungs, which exist side by side with the gills ; it occupies the position and plays the part of the lungs in ourselves, and, whilst useful at all times, becomes of special respiratory value in foul water or times of drought.

The next stage in the evolution of our breathing organs is traceable in the amphibious newts and frogs. These have gills when young ; a little older they possess both gills and lungs ; and in their adult stage lose their gills and breathe mainly by lungs, reverting at times of stress and subaqueous retirement to the oldest known method of supplementing respiration, namely, breathing through the skin. This power of respiring air directly is associated with the conquest of the land. As it is done through the nose, we find

the air passage emancipated from the food passage. The reptiles exhibit a more complete solution of the air-breathing problem. In this, as in all their other faculties, we find amongst them a vast range of mediocrity. Most reptiles are only partially adapted for life on land; many at regular periods pass into a trance during which they respire mainly by the stores of air which their lungs have previously accumulated. In the reptiles we find the last traces of that primeval animal capacity for surface or skin breathing; of true gills nothing but the framework remains. But in none of the known groups of this immense class do we find other than simple bag-like lungs, or a larynx capable of modulated sound. In none of them at the present day is the heat produced in respiration so controlled as to ensure a continuously periodic high vitality.

From some unknown members of this mediocre class two offshoots have sprung in which the faculties of breathing amply, of sustained activity, and of voice production, have been perfected. Among birds we trace the evolution of the most perfect lungs that are known; of the most continuously active of beings; of the most indefatigable of songsters. Amongst mammals we can follow the elaboration of a less aërial type of breathing; but, in accordance with their closer touch with the ground and the acquisition of great size, we find in them a means of inspiring and purifying great tides of air, an immense store of latent energy, and the most varied powers of voice and speech.

The working out of these capacities in each group is a problem of great interest. In birds the lungs are small, the windpipe long, and the organ of voice at its end, not in the throat at its commencement. Birds, therefore, are ventriloquists. From their lungs spring a number of air-sacs which buoy up the viscera as on cushions, line the skin, and often penetrate the very bones and feathers. To inflate this system a dual mechanism is provided. When stationary, the bird may raise and lower its ribs; when flying stiff-breasted, it lifts and depresses its flexible back. In either case two results follow. Compression involves not only expulsion of air from the lungs, but from the air-sacs through the lungs. Expansion entails an inrush through the lungs into the air-sacs. Thus the air in the lungs is wholly tidal. The expiration of combustion gas and the inspiration of fresh air are thoroughly carried out, in which processes the function of the air-sacs is not to act as respiratory organs directly, but to subserve this ventilation of the lungs by increasing the inward and outward wash of air and carbonic acid.

This rapid rushing breathing stirs the blood. The muscles, fanned as by a draught, precipitate their activity in a series of superbly adjusted movements. The tissues burn well. Fuel has to be continuously supplied. Food is imperiously needful, and the unappeasable, proverbial appetite of a bird becomes intelligible to us. Heat, too, increases. The feathers check its radiation and conduction. A nervous

control governs its uniformity, and there results a higher temperature than any we can healthily evolve, and one that for the first time in our *résumé* of living beings is unaffected by that of its surroundings. A hen's temperature is uniformly 103 degrees Fahrenheit; a swallow's, 106 degrees.

The production of voice is partly voluntary, partly mechanical. The adjustment of the slit just above the lungs and the rate of vibrating its edges are modifiable muscular actions. The call note, the migration note, the mating song, the alarm note, and the mimicry of parrots and song-birds are controllable responses to an impulse or an audible voice. But the ordinary breathing movement, which underlies it all, has become part of that unreasoning mechanism over whose starting or finishing birds have no voluntary control. The combination of superb singing powers with high vitality and spacious breathing marks the bird.

In the mammals the lungs are capacious; but the amount of really tidal air is a mere fraction of the whole, and forms a top layer, from which the great mass that is stationary gains its oxygen, and into which it diffuses its carbonic acid. Thus, between the lungs and the tidal air is a diffusion-chamber. Every beast and child fills this with its first breath and never breathes as deeply again.

Movements of the lungs are those of enlargement and diminution. Both of these are effected by the chest and by the diaphragm, a device peculiar to mammals. Both take place through the nose, as in all

lung-breathing animals save unheeding men; and to purify the air, which for ground animals, such as mammals are wont to be, is too harsh or spore-laden for immediate diffusion in the lungs, this nose is elaborated within and without. Its chambers are subdivided by a scroll-work partition that converts them into labyrinths. Inspiration through such tubes now becomes more effective at the outset; and as the wash of air whisks round the corners it deposits some of its impurities on to the soft membrane that lines them, and from the middle part of the nasal passage the air, toned, purified, and warmed, goes to the diffusion-chamber.

The maintenance of activity in mammals, though less impressive than in birds, comports well with their needs. More groundlings than these, their quest for food is more deliberate, their meals heartier and with temperate intervals. Their reserves of strength and material are greatly in excess of immediate needs. The combustion changes of their muscles and glands furnish abundant heat, whether by the patent or hidden activity of these organs, which is evidenced by the dark colour of their flesh. Protected by both fat and hair, this heat is but slowly lost, and the relation of gain to loss is regulated by a nervous control that is centred in the capacious brain. So accurate is this adjustment that man and beast preserve their several temperatures under hot, cold, and changeable climates, and thereby ensure that continuance of activity which is one reason for their dominance.

FIG. 27.—The Common Dormouse.—(*From a specimen in the Manchester Museum.*)

In this, as in all other excellences, we can trace a series of steps from the lower and more variable condition in reptiles; for the lowest mammals have still no even temperature, nor do they suffer fever from a rise of many degrees.

In the development of every child and whelp the heat-centres and heat-mechanism are only gradually steadied and rendered independent of cold or heat; whilst in the winter sleep and spring awakening of the dormouse, bat, and bear we see strength of constitution that endures a quick change of 30 degrees without experiencing any harm. At such moments, which break a long sequence of still winter days and preface a still longer period of activity, these hibernators show a reptilian fluctuation and toughness.

The reserve and rare display of full mammalian activity is well expressed by the voice. The calls, chatter, and songs of birds rarely cease; their notes of warning, companionship, or exhilaration signal their presence and arrest us. But with mammals it is otherwise. The majority only roar, cry, or trumpet to sound an alarm or in rare moments of combat and excitement. Even the dog's bark is a domestic refinement. The highest group, that of the monkeys, is the only querulous and chattering one, and this habit seems to go with active, arboreal, and social life. But, whether silent or vocal, all mammals possess a larynx similar to our own, and it is the nervous control and adjustment of the vocal cords, of the mouth and of voice-production, that give pre-eminence in

song rather than any structural difference which the anatomist can detect. In this, as in all other bodily excellences, the higher type of brain is the seat of success.

Throughout this long series of breathing, heating, and sounding mechanisms we see the conquest of the air, and the inward use of oxygen for effecting movement, for maintaining that destructive aspect of the double process of life in virtue of which existence and growth are alone possible. But deeper than any analysis we have yet made are the adaptations of animal structure to ensure its increasingly efficient working in passing from water to land, from cold to warm blooded beings, from a silent to a vocal life. The heart and blood-vessels, even the blood itself, share in the advance, and become in birds and mammals divided into two systems, one of which receives aërated blood from the lungs, whilst the other receives the waste from the tissues. From this change all the tissues gain advantage. The muscles become more thoroughly oxidised, and therefore stronger. Their tone reacts on the body generally, and on the nervous system in particular. The heat they exhale becomes more generous, and the more abundant food they require as fuel stimulates more strongly the glands of the body. The trembling balance of life becomes steadied by a firm central nervous control, and its two emulating processes—the downward pull of oxidation and the upward thrust of nutrition—are intensified in the maintenance and growth of every part.

CHAPTER VII

THE SENSES OF ANIMALS

The action of the Nervous System as a means of response.—The procession of animal life from simplicity to complexity of structure, each phalanx fitted to an existence varying in richness of contact with itself and its surroundings, is a choric response to calls upon its nature that ages of trial have evoked.

Every living thing is an old hand. Its choice of station and movement therein, its choice of food and mode of breathing, its structure and the relation of the component parts, are traditional and reflect the heat and cold, the light and darkness, the hunger and plenty of many generations. Some mighty control has guided the steps by which each section of this complex composition comes orderly into existence, sustains itself there, develops, founds its family, and after a day, a year, or a century makes room for its fellows, leaving traces which cannot be mistaken of the part it has played. The organisation of each being, and of the pageant of which it is an assignable part, exhibits signs of that orderly control and relationship to the course of events within and without

itself which is one of the most impressive facts of natural history.

The visible sign of this harmonic grace is the nervous system. Placed as a mediator between the conduct of an animal and the impulses that arise within it or that fall upon it, the nervous system determines that life and conduct shall not be a spasmodic response to every call that circumstances make, but that the general well-being of the race shall be consulted, and that in each life-history traditional answers shall be given at first, until education has conferred the power of a strong individual line of conduct.

The nervous system co-ordinates the activities of different parts of an individual being in order to produce successful movement, good digestion, and adequate breathing. It interprets as sensations the stronger knocks that fall upon it from the outer world, and to the tapping of light, sound, heat, odours, tastes, and the like it answers by so many perceptions. It responds to the calls that arise from within an animal, and receives every moment of each day messages from the organs that tell the condition of each one. If all be well the messages are imperceptible to us; if any part be weak, its call upon the nervous system becomes louder, and, if not silenced by adjustment of its need, we ultimately become aware of that which the nervous system has known all along, and we call it hunger, pain, desire.

Besides these faculties the nervous system is the

seat of traditional and individual memory. Through the long succession of days and nights that have lightened and darkened animal history with their alternate periods of greater activity and less, the nervous system has attained a rhythm which tones the activities of the body. This memory of bygone recurring conditions is preserved for us in the slow swing of the brain, which controls the impulse of the moment by the set of its own impetus, gathered through generations of alternate periods of rhythmic change into a fundamental beat. We awake and sleep not only because the sunrise and sun-setting call us to uprising and downsitting, but because in our life and that of our fathers the rising sun and gathering darkness have impressed on our being day by day and night after night an alternation of activity, rapid heart-beat, daytime breathing, with relaxation, slower pulse, and deeper breaths. At our usual hour for sleep or wakening we tend to either, though dark blinds or bright lights may delay our response to habit. So the flowers that close at night will shut their petals even though we turn their night into day. Our fundamental action, if not, indeed, our entire conduct, is thus no immediate response to the calls that arise within us or that fall upon our senses, but is determined to a variable extent by the traditional and by the periodic response of the nervous system that has been established by habit; and to this habit it remains true, though for varying terms in different cases, even if the original stimulus that

called it forth is removed or even opposed. This faculty of the nervous system has been happily called organic memory. If the conditions of life were unchanging, such a faculty would be unimaginable. But change—secular change—is of the essence of life, and the fuller the life the more generous in number and amplitude of swing are the conditions under which it flourishes. Not only day and night, winter and summer, seedtime and harvest, set going the inward pendulum of animal life, but the life and death of their associates, the swing of the tides, all the great secular movements, beat with alternating force upon the receptive nervous tissue. Upon these leading motives that create habit others are superimposed. We learn to walk because the brain has learnt to respond without effort along the trodden paths of nervous life, and is free to learn the new ways of upright adjustments.

Organic Memory an aid to Developmental Study.—It is helpful to remember that once the nervous system has established a periodicity, that then, like a pendulum, it will continue to swing without the repetition of the push that started it. For by such a metaphor we are able to picture the development of an animal in a new light. Nothing is more wonderful, nor more familiar, than the moulding of a life in darkness, and the gradual revelation of its conduct, at first animal, then racial and traditional, and, lastly, individual. But if we admit that life preserves a memory of that which it has long experienced, and

needs not always outward objects to assist that inner eye, then the marvel of animal development becomes a more rational process to us. The eye, which ages of experience of light and sight has brought to near perfection, is moulded without a flaw in darkness; the hands, which have developed by grasping, are formed without a movement; wings are made ready where no air is and where stillness reigns. The responses which are to govern conduct are developing there also. Each unwavering act in this bodily and psychic drama has a long history of effort and failure and success behind it, and here it is summarised in a few weeks of unchanging darkness. But if the eye reacts without light, the formation of the eye may not require the original condition which called it forth. All we know of development seems to show that from the commencement of life each being has a memory, and that each organ plays some part in starting that memory into life. Each part of us is a member one of another.

The most important of these organs and the earliest to appear is the nervous system, for that has the most complex history to recapitulate. But for its full epiphany its memory has to be stimulated by a substance that comes from the thyroid gland, passes into the blood, and, carried to the brain and elsewhere, evokes the series of changes that help to build up a normal child. Should this gland fail to act efficiently, stunted mental and bodily growth result. The child is numbered with the feeble-minded. But

now, let that organ be taken from some other animal, say a sheep, and its extract be given in doses to the dwarfed being, there will often result a gradual change. The needful stimulus is taken up by the blood, carried to the brain and body, and there evokes the hidden and arrested growth of the stunted parts.

In such a way many organs play their part by exciting the activity of others, perhaps far away from them; and to this principle we can attribute the strange and orderly persistence of organs whose primary use has disappeared. The gill-slits, for example, which recur with unfailing regularity in the development of all vertebrate animals, are only used in their primitive sense by fish. But in higher animals their walls give rise to thyroid and other glands that serve to excite the growth of the neck and larynx, and without these glands and gill-bars, which in fish have a totally different function, our development would be imperfect and retarded. Or, to take perhaps the most striking case—the change from youth to manhood, and the corresponding change in animals—a stimulus affects the whole body, alters the voice, broadens the chest, beards the face, and intensifies the conduct. In animals, as we have seen, so great is this change that the colour and eyes, the limbs and skin, undergo a complete metamorphosis: their movements and habitat are exchanged for new ones; the bird, fish, insect, and even certain worms, become different beings. When the change is less radical, as in the growth of antlers and resonance of voice or ferocity of manner, we

recognise the same mode of response of the animal's nature to a stimulus that sets up new development.

The Organs of Sense.—When this view of animal life and development as an orderly response to inward and outward stimuli has become familiar we are able to consider the nature of the senses of animals. The organs of sense are such as originate a message of a definite kind destined for the nervous system. Besides the five senses we have a muscular sense, one of heat, of cold and of pain. In addition to these, messages too faint for our brain to interpret are passing to it from all parts of the body and informing it of their several conditions; to which messages it is able to respond by assurances of which we are totally unconscious. The good results of rest, fresh air, change of occupation, are the outcome of such toning effects of the nervous system on the muscles and organs generally, of whose needs we are only vaguely conscious, but to which the nervous system responds with more than a physician's skill and promptitude.

In dealing with the senses, therefore, we shall consider these subconscious senses, as well as those of sight, hearing, and outer impulses.

The psychical phenomena of animals present a marked contrast with the physical. In structure and mode of development animal life presents variations of endless diversity on several themes. The complications that adapt creatures for life under water, on land, and in air are of the most diverse kinds, whereas the fundamental instincts possessed by this

organised array are seven or eight only. Indeed, if we extend our researches to the lowest animalcule, we find that in it all the essential responses occur which form the themes of the fugues in higher animals. Sight, taste, touch, smell, balance, temperature, and parental instincts, are distinct although there is no eye, no ear, no tongue, and no specialised organ of any kind. Even the element of choice is not absent, and in the lowliest animal the psyche decides what to eat, what to absorb, when to retire from or advance to light or some counter-attraction. Indeed, we may go further than this and say that plants, and even the lowest plants, possess all the fundamental responses. They respond to light, they perceive odours, they choose what to absorb and what to reject. They are sensitive to shock, and even possess sense-organs of a rudimentary kind. In an organism devoid of a nervous system and without any organs of a specialised character all the responses are present, and they direct its life. The astounding diversity of animal and plant life, therefore, only gives expression in a thousand ways and with added clearness and fulness to the responses that their most degraded member possesses; and though writers have ascribed similar ethics to the dust, it is probable that this fundamental psychical uniformity of living things forms one great character distinguishing them from the not living.

The reason of this uniformity does not seem hard to find. The essential objects and conditions of life are everywhere the same. Maintenance, development,

and family or racial cares are its chief aims. Light, vibration or pressure, touch, odours, heat, and dryness or wetness, are its chief conditions. Each of these changes with greater or less regularity. The alternation of day and night, of heat and cold, tell upon all living things. The prehension of food involves the sense of contact with bodies of many kinds; whilst movement involves changes of pressure. Growth and development introduce new factors. The presence of active enemies or of inimical conditions tests the race. For the lowest animal, therefore, some perception of these fundamental conditions, some power of response to their changing quality, some means of meeting emergencies, seems essential. The surprising result is that even the simplest organism gives no hint of any different life than that pursued by the higher ones. All the senses, dim though they be and exercised without organs, are there. The conflict of ages has totally obscured any primitive life. The simplest creatures are old hands, and tell us nothing of what life would be without the power of response.

But though we are denied insight into the beginnings of adaptive response, we can still trace its development in the many and complex forms of animal life.

In fact, life depends upon these fundamental responses to living or non-living agencies. To us, in whom the enjoyment of the senses is a luxury, there is always a difficulty in appreciating the close, necessarily responsive touch in which the simpler organisms

live with light, water, and air. A plant moves towards the light, its roots track the watercourses, its leaves respond to the quality of air, because in these acts it finds the materials for food and new life. In the same way these old responses form the basis for animal actions. In them the senses are not emotions or perceptions apart. They are invariably bound up with a movement or adjustment which has to do with the preservation of life; and these adjustments are no new acquisition, but are traceable in the humblest living thing. The origin of instincts has been needlessly obscured by overlooking the fact that 'sense' is only a link in a chain of action, and also by treating organs of sense as things apart, instead of regarding them as inseparably linked with essential adjustments.

The Senses of Shrimps.—Instincts are combinations of these old responses. We may take a shrimp as an example. By day we see it lying motionless in the sand or clasping a branch of seaweed. By night we find it swimming with great vigour at the top of its prison-water, its heart and breathing organs beating at a great rate, its colour altered from brown to blue, and its nervous system extremely highly strung and sensitive to shock. At the least alarm it will now leap out, whereas by day no ordinary disturbance would cause it to forsake its chosen spot. The tone of its being has been altered, and after persisting through the night this agility will give place at daybreak to the more sluggish habit of its sleeping hours. In recording the behaviour of an animal, therefore, we

have to consider its nervous condition, which is a function or outcome of a long succession of days and nights. By turning its night into day and day into night we find that for the first day or so of experiment the change of tone still occurs at the appropriate hour. Thus at nightfall, in spite of artificial light, the animal's colour deepens into red, then to green, and finally to blue; its limbs, heart, and breath take on a new rhythm, which endures for a night and then disappears. In the same way, if we prevent the morning light from making itself felt, the shrimp will still, for a day or so, time its recovery from a nocturnal bout as though informed of day's appearing. In fact, the nervous system is the master, and for a while its innate periodicity determines the rate of the animal's activity. This result shows what a supremely important part light and darkness play in animal economy. Continued bright light shocks it to stillness; dim light gives it the necessary suppleness of limb.

But now, suppose this action worn down by the constant effect of continued light or darkness; we have then the shrimp in a more responsive mood. The tone of its surroundings now influences its colour in a more direct fashion. On light backgrounds it quickly assumes a pale tint. On dark ones its red and brown pigments produce a dark tone. If we cover its eyes this faculty of sympathetic colour-change is abolished. The brown colour persists under all conditions of illumination, and we thus conclude that the skin is influenced not so much directly by light

as indirectly by the stimulus of sight, which is transmitted to the skin by the nervous system. Moreover, as the colour of the animal is deposited in the muscle-pigments as much as, or even more than, in those of the skin, and since the colour-changes of the muscles follow those of the skin, it is evident that the eyes govern changes in the muscle as well as those in the skin. We are led to look upon the eyes, therefore, not only as organs of sight, but rather as one link in a chain of response which is evoked by light from the whole animal. From this point of view the eyes, acting upon the nervous system, both govern the colour-relations of the shrimp and give the tone to its muscles and general activity.

In a somewhat similar way we may look upon the response to vibration, the sense of pressure and of equilibrium. The shrimp has two 'ears,' placed in the first pair of horns, or in some shrimps near the end of the tail. These ears are hollow balls containing a solid body, either grains of sand or a small block of lime; and it has been found by experiment that accurate balance during swimming or walking is dependent upon the healthy condition of these ears. Like the eyes, they communicate with the muscles and skin by means of the nervous system and have the faculty of compensating any tendency to upset or overturn. They register every vibration that the waves cause or that movement induces. These ears are, in fact, organs of touch with a delicate balance and intimate connection with the muscular system;

and though almost every part of the skin of the shrimp, and in particular its legs, is provided with sensitive hairs, and is to some extent sensitive to change of pressure, such as a wave or a movement implies, yet the ears by reason of their position near the brain have a more commanding influence on the whole body —an influence they practise even in times of peace.

The sense of taste or smell plays such a large part in animal life that we must consider it as a fundamental response; yet in the shrimp, as in all animals, though so important, this sense has no well-defined organ through which it works. All we know is that certain hairs on the upper lip and antennæ, like those of a cat, act as feelers, by which the neighbourhood of food is recognised. The response of the body to this sense is a complex one. In a chain of concerted action muscular events begin that stretch from one end of the body to the other and engage the activity of many limbs. The food of the shrimp consists of small bivalves, which it finds amongst the sand in which it burrows. The little shell is picked up by the big claws and transferred to the mouth. Here the excitement of the upper lip and jaws spreads to the lower lip, and to limbs further back, as well as to parts further inward. The mouth begins to water, that is, the digestive juices are prepared; and so the whole series of digestive processes—the dissolution of the food and its absorption—are linked up as a composite response to the smell roused by the discovery of food. Yet this response is ultimately referable to the property of

distinguishing and preferring chemical substances, which enables all living things to absorb nutritive substances when surrounded by a mixture of heterogeneous bodies.

It is only in some of the higher animals that the organs of sense become so highly developed and the perceptions arising through them so well defined that sensations become phenomena apart from those of motion, digestion, or of others immediately concerned in the welfare of the body, so that we cannot yet resolve their complex actions into the simpler responses from which they have sprung.

The Origin of Sense-organs from the Skin.—The skin, upon which the outer world impinges, contains the sense-organs which receive and transmit its messages, and the deeper parts of the skin develop points from which their needs emerge. Thus, upon any organism a double set of impulses falls, one from without, another from within. Each of these is at first intimately connected with the fundamental acts of life, and in order to correlate the supply indicated from without with the demand indicated from within a nervous system has been gradually elaborated. In the first instance it appears to be related rather to the efficient response of the body to the external messages—pressure, food, light, and so on—and in particular to movement. But it is clear that, since these responses are of vital importance, they must be correlated with the inner needs of the body; and so there come to be not only a nervous regulation of move-

ment, a response to vibration or to food, but also an inner mechanism by which the food-canal, the breathing-apparatus, and the other internal organs are brought into nervous connection with the outer mechanism of skin and muscle. In other words, we see the outline of that control and perception of the outer world by movement, prehension, and touch, and the satisfaction of the needs of the inner world of hunger, growth, and racial cares, that is roughly indicated by the terms central nervous system and visceral nervous system.

The question may perhaps be asked, Why have animals developed a nervous system? The answer, so far as we can give it, bears upon the last discussion. Animals move freely and eat solidly. These two facts go together, and have led to an inevitable distinction between the outer locomotor and inner nutritive regions. Now it is clear that, even if no formal nervous system exists, animal movement demands and possesses a directive and controlling influence. Further, as we know, this regulated locomotor mechanism is able to transmit food to the mouth and to inhale water or air, and the body is able to move the food from place to place in satisfaction of its needs. In other words, animals, even the simple, such as polyps, have a virtual nervous control of their organs of movement and of their visceral organs, and a correlation between the two. Movement, then, and solid food have, so far as we can see, been the two factors responsible for creating the need for that control which is simply

emphasised in the primitive nervous systems, such as those which jellyfish and starfish possess. In fact, the development of these animals shows that the muscle and skin are at first continuous, and the strained threads that connect the two, as they separate for their respective functions, become the nerves for emphasising movement. In a similar way the food-tube is at first a part of the skin, which becomes pitted in and grows inwardly, and the connection between its layers and the muscles and skin of the wall of the body furnishes the basis for its visceral nerves, and for the correlation between their demands and the exertions of the locomotor organs in the prehension and supply of food. Thus the nervous system of animals is intimately related to the primary conditions and needs of life, and is organically descended from the neuro-muscular skin and the neuro-muscular food-tube.

The development of animals, even of ourselves, shows how close is the relation of the nervous system to this primitive plan just sketched, and how intimately the sense-organs are connected with the skin. The skin in all animals is an organ of one or more senses, and from it arise the essential sensitive parts of those sense-organs, such as the eye, the ear, and nose, which seem to be unrelated to it. It would appear incredible that the retina of the eye, the equally delicate and more complicated lining of the ear, should be a modified patch of skin; yet such is the case, not only in one group, but in all; and, indeed, in some groups it is possible to point out a series of stages in

which the eye commences as a mere open pit, then develops into a closed vesicle, and passes by degrees into an organ whose complexity approaches, if it does not attain, that of our own; whilst with regard to the ear, the skates and certain other fish still retain an open tube by which their ear is placed in communication with the skin.

In the early life of animals the nervous system itself is at first in close contact with the embryonic skin, and only gradually sinks down to take up its position in the enclosing bony or gristly tube that is to form the vertebral column; whilst in many primitive forms its connection with the skin is retained throughout life. The nerves which direct movement are actually developed in connection with the muscles and skin, much as in the case of a jellyfish or sea-urchin; whilst those nerves that announce hunger, desire, and generally the condition and needs of the inner organs, are derived ultimately from ingrowths of the surface layer. The two sets of organs—the outer or directive and inner or visceral—become inter-connected by nervous ties that provide pathways whereby the need for food or breath, for example, is able to set in motion a movement of the body that tends to supply that need. So we see a full animal is quiescent, a hungry one is active. In the reverse way, the sight or taste of food sets going the nerves that connect the prehensile organs with the digestive ones, and so prepare the way for the reception of food. So shortness of breath induces more rapid breathing, as we see

in fish when the water of their aquarium has become partly exhausted. In short, whilst the movements of an animal are stimulated by light, heat, and outer agencies, they are controlled by a nervous mechanism that is not only related to that control, but is also concerned in satisfying the inner desires by those movements.

Gradually these adjustments become not only automatic in their working, but by their repetition induce a second self, a periodic heightening and lowering of the central governing control, through which the rate of automatic working is rendered steady for long intervals and is protected from becoming spasmodic and from changing with each change of scene. Thus we find choice becoming obedience and obedience becoming tradition, giving, as it were, a direction which the answer may take, though not determining the intensity of its response.

The warm blood of the higher animals creates a further buffer between them and the changing conditions around their bodies; it wards off from them those changes of temperature which sink their less fortunate relations into stupor or death.

The value of this mechanical and traditional tendency is easily misunderstood. We need not look upon it as necessarily converting the whole life of an animal into a series of purely automatic actions. For if we steadily keep our outlook on the gradual evolution of self-consciousness, we shall see in this stiffening of action the necessary prelude to advance in the

higher responses. It is not merely because we are relieved of decision about manipulation that would otherwise check our advance, that as speech, draughtsmanship, or reckoning become easily performed, that therefore language, art, and astronomy have become a more perfect expression of the universe. The unburdening transfer from act of choice to act of drill and from the strain of memory to the habit of tradition allows not only further advance to be made, but preserves the past and forms when complexity has been gained a point of departure for responses to messages which before were too high for us to interpret or hear. These messages, coming either from within or from without, are no new things, but, like the pulses that beat upon us all day long, were unperceived till the insistent voices of needs were stilled and we became attuned to a more receptive pitch of nervous strain. Thus upon the solid groundwork of embodied and self-contained, self-regulating tradition the needs of maintenance are satisfied, leaving us free, not to sink into the torpor of automatism, but to respond to finer impulses which the cares of maintenance had hidden. The needy artist must first make his bread and then practise his art ; and the making of bread creates the necessary organic preparation for æsthetic perception and work. Even so the classes of animals richest in manual work and tradition are alone they which have æsthetic preceptions.

'For to him that hath shall be given.'

The performance of work done out in the open leads in each class to a capacity for new response, and therefore to greater variety of handiwork.

Amongst the Protozoa, those are the most complicated and the highest which have left shelter to inherit the fuller traditions of the open sea. Amongst the zoophytes there is one family—the siphon-bearers—that has surpassed all others in gracefulness and variety of shape, in intensity of colouring and virulence of poison, and it is this family of the blue velella and the violet 'Portuguese man-of-war' that has had no rest, that has felt the unceasing beat of the sea, and without intermission has been stimulated to action. A more familiar example is the hydroid-polyp of the shore, with its simple structure and plant-like responses, and the jellyfish that arises from it but strikes out to sea, where its eyes and ears, its muscles and poison-organs become elaborated through its constant adjustment, varying to meet the changing action of light and waves and the choice of food.

But it is on land and in air that adjustment becomes more arduous, oxygen more plentiful, and advance, though difficult, more pronounced. The play of light, heat, and vibration, the influence of weight, the sources of friction, the steepness of hills, all tell with greater force on land than under water. To those animals that can make the adjustments and endure even for a few months the rigour of a changing climate a higher place is assured than to their brethren

of the sea; whilst the old, the irresponsive, adopt hermitage in the soil away from the stress of life. So it is not till the physical adjustments become varied, sound, and performed with ease and without thought, that we find the dawn of intelligent response to the living factors of the situation; the response to an impulse, not themselves, that has been at work all along, but is hidden from animal life until a certain stage of responsiveness has been attained. Then as racial instinct, the spirit of the hive, or by whatever name we call it, sometimes in solitude, more often in companies, the finer issues of life are felt and responded to by those that generations of manual work, delicacy of touch, and observance of open-air changes have cultivated. Birds and insects rule the air by unthinking adjustment. Man rules the earth by thoughtful adjustment. His success is due to his power for profiting by experience, both in his individual and corporate life, and thereby rising in capacity for response to more and more complex motives, whether for good or for evil.

The domestication of animals may illustrate what far-reaching results flow from a simple act when that act can be repeated and modified in the light of experience.

In common with other carnivorous animals man kills for food, and in general with as little foresight as they. Nevertheless, here and there a genius will have noticed that, after a successful chase, to keep alive that which is not required will give power. And

these more far-seeing warriors, having begun to capture as well as to kill, acquire wealth and fame. To the consequences of this simple act more than to any other, civilisation is indebted for its development from the 'pack,' through the pastoral to the political state. The Australian remains for us the nearest of all living races to that primitive hunting state; and the nomad shepherds of the East illustrate the art which has given rise to 'capital' and to 'pecuniary' advantage amongst the more advanced races.

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CHAPTER VIII

THE COLOURS OF ANIMALS

The Primary Meanings of Animal Pigments.—In man and creature colour is sacramental. Complexion in man is a sign of racial constitution and temperament, and colour in animals is the expression of that hidden working which controls, and is controlled by, their life.

We regard, and rightly regard, the body as fuel for fire; its activity as the outcome of a combustion which is fed by food and fanned by air, the engendered heat being carried by those hot-water pipes, the arteries, to the remotest outworks of skin and muscle, of bone and nerve, there to replenish the loss which secretion, movement, and nervous activity involve. And as from coal we can obtain not only heat, but tarry matters and aniline dyes, so from the slow combustion of the tissues does the body deposit those grains of matter which, when exposed to the light and air, become pigment, as a cut apple goes brown or a chipped toadstool blue. Colour is thus distilled, as it were, from the whole body, and resumes its essence in a seemingly surface finish.

If we now review the colours of animals, we are

struck by this influence of light on their distribution. A dark back and a pale under-surface form the most general of all schemes of colouring. Insects and worms, shells and starfish, fish and frogs, birds and most beasts, through a vast category of marine and terrestrial forms, display the white breast. Squirrels, the most vividly coloured of mammals, still keep the rule ; whales and fish agree in the contrast of their dark upper sides with their white nether surfaces. Blue and brown butterflies are only so when seen from above ; and if we turn up the palms of our sunburnt hands, we find that there too pallor is more evident than on the upper side. Colour and light-exposure, pallor and light-starvation, are correlative terms. As the green colour of plants fades in darkness and shade-leaves, so the nether parts of animals are bleached by the lack of light.

To confirm this and give the mind living hold upon its significance we must apply the test of experiment. If light induces colour, and darkness prevents its appearance, then we should, by inverting a young animal, obtain some evidence as to the present-day applicability of this principle. This has been done both artificially and by that age-long trial that natural experiments involve. Young plaice have been grown in a tank, lighted from below and darkened above, so that the under-surface of the fish, which is normally turned away from the light, was exposed during the hours of daylight to the light reflected from a mirror. After an interval of a few weeks several of the batch so

treated were found to have developed spots of colour on their under-surface, and thus to present an ambicolourate appearance. Ultimately one of the fish became almost totally embrowned, and lost all but mere traces of its usual silvery whiteness.

More convincing even than this experiment is the one which Nature herself has carried out on the sucker-fish. The sucker-fish is a parasite hanging on to the bodies of larger tropical fish for the sake of the crumbs that fall at meal-times. To ensure its hold the fish has converted its dorsal fin into a strong, transversely ridged sucker, which it applies to the upper side of its host, and thus views the world standing on its head.

Its back is in shade, its belly in light, with the result that the usual colouration of animals is here reversed—its back is white and the belly dark, almost the only exception to the otherwise universal rule ; and so accustomed are we to it, that when we first handle a sucker-fish we involuntarily turn it upside down and unconsciously acknowledge the strength of that association that leads us to regard the dark surface of an animal as the upper one.

Whilst we can thus conclude that the shaded parts of the body become pale and the exposed parts dark, there are some natural experiments upon the total bleaching of the body by generations of cave life. The cave newts of Carniola, in Hungary (fig. 28), have become famous. They are milky white blind newts, a foot or so in length, and live in the darkness and cold of subterranean waters. Unlike their allies, the

askers, which are coloured on the back, these cave newts are without any trace of pigment. That they have lost their original colouring subsequently to adopting cave life is a conclusion rendered highly probable owing to the discovery of still another colourless species in South America which is related to quite a distinct family of darkly coloured newts, and is borne out by the occurrence in the same caves

FIG. 28.—The Cave Newt of Europe (*Proteus anguineus*).
(*From specimens in the Manchester Museum.*)

of white shrimps and bleached insects, whose relatives lead a free life and possess a coloured skin. But this bleaching is only permanent so long as light is excluded, and if these cave newts are brought into daylight they develop in the course of time a dark skin, and after a few months become almost black, the change being most marked on the back of the animal. Experiment thus confirms the power of light rapidly to excite the formation of colour or pigment, and the power of

darkness to prevent the appearance of colour or to destroy a pre-established colour in the course of generations.

With this thought we may look out on the colours of the animal world and observe the broad general agreement between the arrangement of these tints and the green colour of plants. The two sides of an animal differ as do the two surfaces of a leaf ; the upper one, being the more exposed to the sun, is the darker ; the lower, more shaded surface, is the lighter one. Animals, such as worms, that keep one end of their body root-like buried in the ground become at that extremity bleached, and those that are altogether excluded from the light, like a tuber, are totally colourless. A plant grown in the dark becomes pale and chlorotic ; an animal, though more slowly, becomes no less drastically etiolated. Transported from darkness to light, the leaves of a cellar-grown or shaded shrub reassume their green colour, and with no less certainty the colourless troglodyte becomes dusky when illuminated. Nor is the full light of the sun necessary for the development and preservation of the colours of animals and plants. In a dim light vast numbers of jungle plants, forests of brown and red seaweeds, multitudes of crepuscular, creeping things, and deep-sea fish work out their life with as full a colour as their relatives and brethren of the sun. The mole and bat are no less deeply coloured than the sparrow or skylark ; the pygmies of the dark Congo forest are brown as the tribes of open country ; the moss

of a waterfall on which no light shines is as full a glossy green as the velvety covering on a south wall, and shows us that though light and colour, darkness and pallor, are causally related, yet the intensity of the necessary light and the need for its continuous employment and the mode of its working have to be considered before we can unravel the tangled problem of animal colouration.

In a plant these factors are comparatively easy to determine. The green colour we know is associated with the production of the plant's food. In the leaf, starch or sugar is formed as a preliminary step towards building up the plant-substance by union with juices that rise as sap from the roots. For the efficiency of the leaf light is requisite. Cut off all light, and the leaf is starved in a day, and dies. Expose the leaf to a continuous direct light, and it is no less infallibly killed, though replete with starch. In the moss and fern tribe darkness and starvation may long be endured with impunity ; in the cactus group intense light and plenty are equally well borne. But, however varied their powers of adaptiveness may be, plants require the green colour for a definite object—namely, to lift the carbon dioxide of the air to a higher power, which in one form we call starch, in another sugar ; that is, the green colour of plants subserves nutrition, and to do this light is required.

In this process of modifying the carbonic acid of the air its oxygen is set free and made available for the needs of aquatic plants, so that by day starch

is formed and oxygen provided. The green colouring matter of plants is, consequently, concerned in the processes of replacing the matter of living substance. Its fundamental importance and its simple requirements explain the ubiquity and abundance of green colouring in plant-life.

Amongst animals there is no such fundamental, widespread, and nutritious pigment. That mysterious and seemingly simple hold upon earth, air, and water by which plants make their living, if it exists in animals, is no prominent feature of their life. Their food is no cunning mixture of gas and water. In spite of fable, the chameleon does not live on air, but on flies; nor does the possession of a green colour by many frogs, snakes, birds, insects, or worms confer upon these animals (with one remarkable exception) the ability to subsist without solid food, even where the green matter has proved to be identical with that of plants.

A plant living in an animal, as plants (Flagellates) do (p. 106) in Protozoa, anemones, and some worms, is only capable of keeping its host from starvation by submitting to be eaten up piecemeal, and should further solid food be lacking the menagerie dissolves partnership. Whatever value we can attribute to animal colouration, a nutritive one would seem to be the least probable, and we turn to the other side of life's balance-sheet, the income of energy, to see if there is any animal pigment which has the property of allying itself with the oxygen of air and of purveying that oxygen to the tissues of the body.

In this quest we soon meet with success. The red colouring matter of blood is such a vivifying substance. The aërating virtue of the blood lies in that colour, and should it fade we become weak and anæmic; should it disappear, we succumb; our fires burn out from need of the oxygen which the red pigment, and it alone, can dispense.

To most animals, as to ourselves, this pigment is essential. All the members of the vertebrate class, cold- as well as warm-blooded, possess it. It gives not only the colour to the blood, but the dark tint to the muscles. Below this class it occurs sporadically in snail, starfish, and worm, conferring upon their blood and muscles a greater efficiency than is possessed by their colourless relatives, and the ability to thrive in stagnant water or amid ill-ventilated surroundings.

In producing the gross colour of the animal this pigment takes but a small share, and it is only when a given supply has done its work and steps aside to make room for the new flow that comes from the marrow of the bones that it is apparently removed from the blood-vessels, transported to the skin, converted into a black pigment, and stored in hair and feathers, there to give rise to the colour of the body.

But the interest of the red blood-pigment is not confined to its wide distribution, its life-giving property, or its usefulness as a source of surface colouring. In its chemical nature this pigment shows a family connection with the green colouring matter of plants. In their purest known state each of these bodies,

the one red, the other green, appear as cousins, related through some as yet undiscovered stock. Each has diverged at some remote epoch along a line of its own, and in course of time produced the substance that we know as the green colouring matter of plants and the red pigment of the blood of animals.

Yet, in spite of this divergence and seeming disparity, we can detect points not only of resemblance, but of affinity. Both have a like, though hidden, family constitution, indicative of a common but remote genetic connection. They occur with unfailing regularity in the higher divisions of the two kingdoms of living nature, and become less constant in the lower members of animal and plant life. In those plants which live parasitically upon the tissues of other organisms the green colouring matter is absent. Its nutritive power of making and purveying sugar, starch, or oil is not required.

In the vast class of moulds, mushrooms, and toadstools there is not one that has the requisite green pigment. Amongst typically green plants there are still more striking examples of the loss of colour following upon the adoption of parasitic habits.

The dodder that infests vetches and clover sucks the juices of its host and loses its livery. The minute colourless Flagellata which abound in organic infusions are cousins to those *Euglenæ* that fill the roadside hollows with a green scum, and if only water and light are supplied to them their colourless bodies reassume the green tint and create a food store from such

inorganic sources. It is just among such plastic, chameleonic Flagellates that we can trace that remote connection between animals and plants to which biology points from whatever side we study it—in infusions an animal, in water a plant; producing starch like a leaf, and yet such starch as only the muscles of animals evolve. Still for long intervals like an alga, and anon swarming in a dense throng like a shoal of microscopic fish; abandoned in turn by the botanists to zoologists, and by zoologists to the botanists, this group of Januses is ever enticing the naturalist to its study, and yet refusing to fit into the categories he has made. From such Flagellates all the families of seaweeds trace their descent, as to the founder of dynasties, and to them also many of the lowest animals and the sponges owe their genesis.

The loss of green pigment amongst animals would thus seem to be due to their mode of feeding upon organic food, which was not only a richer diet, but, unlike the primitive plant food, could be obtained in dark as well as in light places.

When the activity of these dual organisms increased, as it necessarily did in pursuit of fresh stores of organic débris, the need for nourishment increased also. The new and characteristic animal tissue—muscle—demanded both oxygen for contraction and also nourishment by appropriate food, and impressed into its service that faculty for vivifying the body with oxygen which in its green youth was associated with the body colour; and in the lower

animals we see, following the gradual insistence of this respiratory demand, the gradual evolution of a more and more efficient oxygen-carrier. In the shellfish the blood has only a quarter of that oxygen-holding capacity which we possess. In the worms which live where little air is available, the blood is richer, and either green or red. In the vertebrates the blood is always red, richer in oxygen-holding power, and meets the demands created by the growth, bulk, and activity of the body for a continuous supply of oxygen to all the tissues. Of these demands some are more pressing than others, and we can assign the deeper colour of the more active muscles to the great stores of blood-pigment heaped up for their use. Hence the darker legs of a hen contrast with its breast, or the dark flesh of game with the white flesh of poultry, And further, if the generally accepted opinion is correct, that the yellow, brown, and black pigments of hair and skin, to which all the higher animals owe their colouring, are kinds of effete blood-pigment removed from the circulation and dumped down out of the way, then we may look upon the blood as furnishing the pigments which are worked up upon the canvas of skin into such superb embroideries.

We can thus broadly trace the rise of the red colour of the blood to its source in some distant connection between plants and animals, of which its chemical affinity with plant-green is confirmatory evidence.

Evolution of red and yellow fatty pigments.—A no less complex and yet fascinating quest than this of

the history of blood-pigment is that of the yellow and red colouring matters of the lower animals. We all know the red colour of boiled shrimps, lobsters, and crabs, and the change from blue to red which these Crustacea suffer in the process is but an instance of the breaking down by heat of a delicately poised and unstable substance, and of its return to the basal red pigment which we see in the change of phosphorus from red to yellow on heating.

But we are not familiar with the fact that such red and yellow forms of a definite chemical substance run like a thread through animal and plant organisms, giving evidence of a similarity of constitution that appears more and more strongly to the mind as we grow acquainted with these unexpected relationships. The yellow yolk of an egg, the red shell of a lobster and yellow substance of a carrot contain a colouring matter of the same chemical nature. The same material colours the wax of our ears and the visual purple of our eyes. The eyes of birds and reptiles possess yellow globules, scattered amongst the part most sensitive to light; the eye of man and of ape has its yellow spot or centre of acutest sight; and in the eyes of nearly all vertebrates there is a reddish pigment which belongs to the same class of coloured substances. In the skin of fish and that of frogs, which are so highly nervous as to be hardly less susceptible to changes in their neighbourhood than the eye itself, the same yellow and red pigment is abundantly found, and there assumes the form of minute

star-shaped masses (*chromatophores*), which can contract to a mere dot, leaving clear interspaces between one mass of pigment and another, or, again, can expand to a radiate form, branching out and filling the skin with a tracery of colouring. In the same way the skins of shrimps and prawns are dotted over with little mobile bags of pigment, now expanded into star-like forms and rendering the animal of a deep brown colour, and anon contracting to as many microscopic black-looking dots, separated by clear interspaces, and the effect of which is to give the shrimp or prawn a transparent and colourless appearance.

As we go further down in the scale these pigments become still more abundant. They suffuse the skins of most starfish, sea-urchins, sea-cucumbers, and brittle-stars.

This substance, which in its yellow or red form has such an extraordinarily wide distribution amongst animals, is no less common amongst plants. The green substance of ordinary leaves contains it. In all underground stems, roots, and tubers it is present, though often only in small quantities, as in the turnip, or in a concentrated form as in the carrot. In the fungi it produces most of the brilliant orange, yellow, and red effects that so strikingly catch the eye on leaves, palings, and tree-trunks which are infested by moulds. Even amongst the simplest of all forms of life—the bacteria—the same pigment is still to be found. From the lowest to the highest forms of plants, from the simplest Protozoon up to man himself, there

is no large class in which the yellow and red pigments are not to be found, though we may have to search in the remotest and most delicate organs before we find them ; they may confer the most brilliant colour, or be hidden and valueless as regards it.

The meaning of this widespread colouring is not yet fully understood. It may well be an apparatus of extreme antiquity, which has been to some extent supplemented by newer methods. These pigments are occasionally capable of producing starch in the presence of light, but neither so effectively nor so rapidly as the green colouring matter; and it is not unlikely that the green pigment, which is perhaps the most economic machine that life has evolved, was only perfected after the simpler yellow tools had long been tried for the production of food from inorganic sources in air and water.

In the lower plants the red and yellow colouring matter is related to the accumulation of fat and oils, which are stored in the seeds or spores. Similarly, in the carrot, the huge reserves of fatty materials collected in the roots are accompanied by a dense formation of yellow pigment, and in the eggs of animals the same relation between yolk and pigment is clear.

So constant is this association that these pigments have been called fatty pigments, and stand in some sort of relation to the nourishment of the young, whether plant or animal. But until recently the nature of this relation was entirely unknown. The results of some researches on the pigments of prawns

have, however, suggested that they possess a definite nutritive meaning.

In these animals the colour of the skin is due, as we have seen, to minute stellate masses of such substances. These mobile pigment-stars form the 'chromatophores.' But not only is the skin thus interspersed, as it were, with pores, from which the pigments overflow into channels or into which they retire, leaving the channels clear and colourless, but a similar system of pigmented holes and crannies traverses the muscles, the digestive system, the nerves, and the eyes. The whole prawn, in fact, is bathed within by pigment veinings. Along the courses of these channels lies a second series of tubes that contain, in green specimens, minute grains of colourless fat, and if the prawn be starved and kept in the light the fat does not disappear.

If, on the other hand, both food and light are excluded, the prawns, having exhausted what food they had to start with, absorb pigment and fat also; and if such lean specimens are taken out again into the light at the end of a fortnight, they will in the course of a single day show not only a fatty skin, but a far denser accumulation of fat than is to be seen in a fresh-caught prawn. This result points very strongly to the conclusion that the red and yellow colouring matters, even of such highly organised animals as prawns, are, as in some plants, able to form fat out of its simple elements, and are, therefore, no mere decoration, but factories, under the shade of which the

demands of the body for nourishment and of the eggs for yolk, which cannot be completely met by the usual food, are satisfied.

The colour of the prawn may thus have nutritive value, though naturally of a lower order than that of the food taken in by the mouth and elaborated in the passage through the tissues.

The multitudinous minute collections of pigment or chromatophores that star the skin and the interior of the body form so many rudimentary elaborating machines, independent of the digestive system, and differing from it in being able to construct and distribute a fatty substance under the influence of coloured light.

Whether this double mode of nourishment is widely spread amongst animals is not as yet ascertained; but we know that it is extremely difficult to prove, and for this reason—skin-nutrition is a mere vestige of an old process that has been supplanted by the more modern and efficient one of nutrition by the digestive system. The collections of pigment, under whose ægis it operates, are somewhat like the buttons on our coat-sleeves, the silent letters in words, or the muscles of our ears—relics of a time when ruffles were worn, when those silent historians were vocable, and ears, hairy and pointed, twitched.

Nature throws nothing away, and in many a secret drawer preserves documents, yellow with age, that hold her past history. Here and there she still uses the old parchment, an ancient recipe to guide the cook,

but for the most part employs a newer and more elaborate method.

But if the plant-like method of elaborating food from air and water has fallen with animals into disuse, the connection between these old yellow and red pigments and nutrition is still an intimate one. We have seen that where fat is formed such pigment is frequently, in prawns always, present, and we can now see more significance in the alliance of pigment with fat formed out of food on the newer plan of the digestive system, and accumulated in the skin, muscles, liver, and eggs.

Nothing is more common than for oil to assume a yellow colour, or for the seed-coats of some plants or the tubers of others to become yellow or red. In the majority of such cases the colour is unessential, and neither concerned in the formation nor accumulation of the stores.

But as a hint of the part which these ochreous and rufous pigments played in these processes ages ago we have a suggestion of the utmost value, of a former utility, of the need for an historical grip on the facts of nature before their significance can be even imperfectly appreciated.

From such a broad survey of the green, yellow, and red pigments of plant and animal we acquire a standpoint from which we may view the colours of animals in a new light; not sufficiently high to enable us to see to the boundaries of knowledge nor to determine with equal clearness foreground and background, but

at least better than standing on level ground and viewing the occurrence of colour as a miscellaneous and unrelated display.

We see that yellow is a sort of ground colour, from which the red blood-pigment emerges as a later wash. To the former we attribute a nutritive value ; it is the harvest colour. To the latter a fiery touch ; it is the carrier of oxygen and the seat of life.

Movement, that significant attribute of animals, has obscured the meaning of the one and increased the value of the other. By creating appetite and capacity, activity has demanded more nourishment than the yellow pigment could produce, and movement has annulled that stationariness and exposed habits that favour its synthetic power in the presence of light, and in general we only see such yellow pigment in the inward parts of animals.

The red colour of blood has likewise fled the surface and become an internal pigment, bringing the air from the skin, lungs, and gills to the tissues of the whole body.

On the bare surface so created painting has been done by a later hand, and with old pigments worked up into new combinations.

The blood, for instance, is worked up into reds and browns ; from the liver come the green pigments that we recognise as biliary accomplishments ; and even from remoter and baser organs colouring matters are formed.

We know that the skin possesses an eliminating

power, that arsenic, sulphur, and gouty phosphates are transferred from the deeper to the more superficial parts of the body; and the more insight we gain into the colouring of the skin, the more clearly do we see that it is the seat of purification, in consequence of the complexity and bulk of the animal body.

White butterflies owe their white and yellow colours to one of these 'excretory' poisonous substances, and the silvery whiteness of fish is due to a similar though harmless substance. Thus it comes about that similarly coloured pigments are not necessarily of similar nature. The yellow butterfly, the tiger, and the frog contain three different substances, and we have to apply tests before we can separate the old historical yellow of the frog from the later and derived pigment of the tiger and fly.

It is to these three functions—nutrition, respiration, and excretion—and to nutrition first and foremost, that the pigments of animals owe their origin.

In each case the original significance of the pigment may be lost, and a later and apparently merely decorative one be attained. To the study of skin-painting and surface-colouring much has yet to be contributed before we can, as it were, restore the colouring and realise the design. But in such a quest nothing is insignificant, and he who can explain freckles will solve one of the most baffling problems of human or bestial colouration.

The Secondary Meanings of Animal Colouration.—Having thus obtained a grasp upon the meanings

and physiological significance of colour, we may consider its modifications. Harmony with the varied conditions of existence is the note of animal life. The adaptations of colour to serve ends beyond those of nutrition and respiration form part of that general harmonious relationship between animals and their environment.

Amongst these adaptations none are more striking than the sympathetic colourations of animals. With but few exceptions, amongst gregarious species, the attitude and colouring of animals renders them inconspicuous.

Those which rest for long intervals reflect, as it were, the light and shade, as well as the colouration of their habitual surroundings. The tiger's stripes sympathetically render the lights and shadows of jungle grass, amid which it lies concealed a whole day. The giraffe's dappling and the deer's spots give back the sun-images and leaf-shadows that filter through the foliage. The skate and turbot, sole and shrimp, are speckled like the ground on which they long rest, motionless. The skin becomes to all appearance a sensitive plate, upon which, as by a process of colour-photography, is imprinted the general tone and tinting of the surroundings. So sensitive do prawns and other sympathetically coloured animals become that, if given a choice of station, they do not rest until they have adjusted their dark areas to the shadows and their bright spots to the shafts of light. But once having accomplished this, they remain still for a long

interval. The Æsop prawn (fig. 29) of our coasts makes this adjustment with the greatest nicety, and for this reason is not so easily seen nor so widely known as the restless edible prawn. Its pigmentation recapitulates the descending colour-scale of the seashore. Green, brown, and red, the notes of the upper shore, of the lower shore, and of deep water are struck by this *Hippolyte* as we find it on sea-grass, tangle, or ruddy weed. Seated motionless, and almost invisible, it reproduces not only the colour, but also the pattern of its background, and, according as the light is more or less broken up by the bushy or leaf-like form of these sea-forests, so does the colouring of the prawn exhibit marbling or uniformity; and as there is an infinite variety of colour gradation in this water-foliage, of which green, brown, and red are but the most salient tints, so does the livery of the prawn vary through the whole gamut of the spectrum from red to violet. If a collection of such motley be gathered together and supplied with a choice of varied weeds, each after its coat will select its colour harmony and vanish as if by magic.

With a renewed sense of the fitness of things the eyes and the mind of the observer rest contented upon this sympathy of colour between animals and their surroundings. Such orderliness has a special power to arrest the attention. The policy of bees or the flight of birds is scarcely a more finished performance. But the spectacle of such harmony has not

produced its full effect if it permanently arrests the mind and holds it at gaze.

The prawn in its motley is but one of a thousand instances of colour sympathy, and leads us to inquire and experiment upon the mode and material that effect such adaptation, and to judge of its value as a contribution to the enjoyment or more material needs of the animal's life.

It is not only as a symphony which can transport us, without our distinguishing the orchestral elements or the art ruling the composition, that we can view the triumphs of animal life. An artistic mind is, indeed, essential to receive the effect, distinguish its causes, or perceive its relations to other and humbler displays. But biology is essentially human. Of its stuff we are made. That which has gone to make its triumphs—both soldiers and generalship—has gone to make ours. To view them is to see no merely pleasurable spectacle, on which the mind can rest without moving to its analysis. Our curiosity, once set working, discovers that what we at first see is but one view of a kaleidoscopic drama, and finds a new sense of *camaraderie* in similarity of forces and tactics that have won positions for animals and for us.

Viewed in this light, the manner and meaning of harmonious motley possess a wider significance than we at first attribute to it.

All the colours of which the Æsop prawn is capable are due to three pigments—red, yellow, and blue. By mixture or suppression of these three the varied

compound or simple colours are produced, and, as we have seen, the basal pigments—red and yellow—are related to a colouring that, either external or internal, is a thread binding all classes of animals and plants together, and leading the mind to that ancient nutritive significance which such pigments possess. In the case of this prawn that nutritive value is especially clear. As we can assign to the colouring matter and the light-position of the seaweed their several parts in the production of plant food, so to the similar colour and equal immobility of the prawn we can attribute a corresponding though lower economic importance ; and the causes that have favoured the green colour of sea-grass have been also active in producing the green colour of the prawn that rests thereon.

Yet with such sapient conclusions we are not content. Animals are by nature active creatures, and the spectacle of a prawn thus vegetating and growing into its surroundings pricks the mind to ask how the process works. Does a green prawn give rise to green young, and a red prawn to red young, or is there no hereditary bias in favour of any one colour, and the matter left to the choice of the children ? And how comes that banding and dappling which fits the prawn to its weed ? The answers to such questions are slow in coming to a satisfactory fulness, though already much is known. *Hippolyte* issues upon life not in the image of its mother, but as a minute colourless creature, with none of the walking legs it will afterwards possess, and provided with swimming limbs and a flexible tail

that fit it rather for drifting upon the open sea than for arboreal life. Upon close examination the absence of colour is seen to result not from absence of pigment,

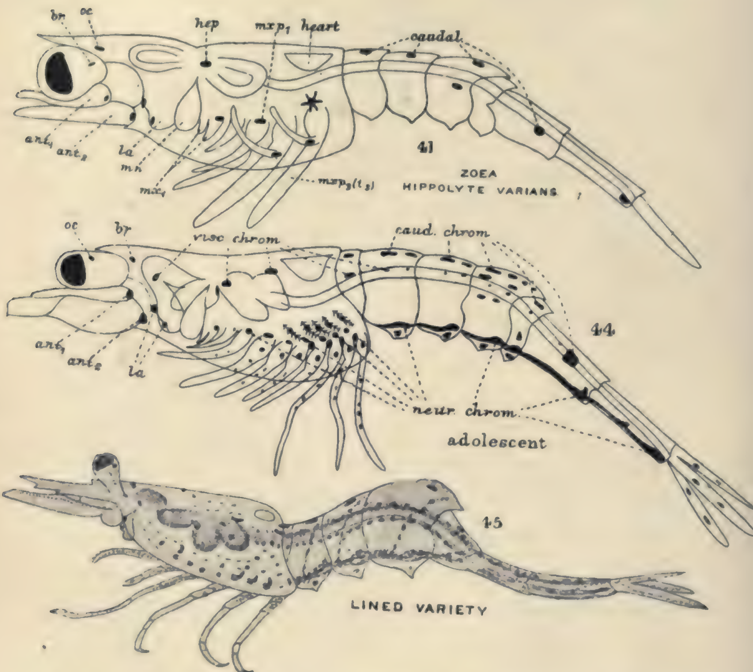

FIG. 29.—Illustrating the Development of Colour-pattern in *Hippolyte*. The uppermost figure represents the free-swimming larva. The middle figure the adolescent stage, when it settles on its weed. The bottom figure represents one of the many colour-varieties. The black spots represent the chromatophores (caudal, visceral, and neural).

but from its poverty; and if a sufficiently strong magnifying power be used, a whitish or greenish tint will be observed. In this respect all families of this

prawn agree, however different may be the colour of their parents. At birth, therefore, H*ippolyte* has no hereditary bias towards this colour or that.

After a life of some days spent offshore among the flotsam of the sea, the young *Hippolyte*, still transparent and almost colourless, is carried inshore, and attaches itself to the first thing that comes handy. If in deep water, the holdfast will be a red weed; if within the tidal zone, it will chance upon one of the many variegated bushes that clothe the rocks; if among the tangles and dense Fucus, a brown weed will be the likeliest anchorage.

On whatever hold it chances the young animal will stay, partly to feed, partly to avoid dislodgment and death by the surf. At this stage its skin is of a great sensitiveness. Experiment shows that if two companies of such colourless young *Hippolyte* are supplied respectively with contrasting weeds, each will assume the corresponding tint in a day, and the colour so formed will increase in intensity until the match is complete.

So on the beach, as the light filters down to where the young *Hippolyte* cling like stranded mariners to the slippery rocks, the prawns respond to the colour of their environment, and before a week is over the resemblance is complete; and should a gale or a low spring-tide set them moving, they will not be long before selecting cover that corresponds with their coat. All have the colour-scale before them, and their choice is made at the start of their career.

Their youth, like that of higher animals, is shaped by early impressions, which come with a force and are responded to with an alacrity that diminish in later life.

Across their sensitive, transparent skin a shadow falls. Scattered over the body, some pigment, insignificant save under a microscope, is present, and in the shadow's path this pigment undergoes a change. By a rule of behaviour that governs the expansion of pigment into interwoven skin-channels, or its contraction into pores, the shaded pigment will expand and darken that area of the body. Further, as exercise favours growth, so does this expansion of pigment seem to induce increase in its amount. Between the existing dots of colour new ones arise, the bar thickens and in a few days reproduces the shadow in tone.

Thus we can trace the influence of light and shade in preventing or favouring the development and expansion of skin-pigment in *Hippolyte,* and in thereby producing that sympathy between the prawn and its surroundings that afford it such wonderful concealment.

The development of the colouring, as well as of the light and shadows, at this critical phase is less well understood. We know that the red and yellow pigments are older than the cryptic colouring they produce; that their value as nourishing, if not also as respiratory, mechanisms explains their presence and antedates this merely decorative effect. But by

what process they are so laid on, toned, and mixed it it difficult to understand, save on the analogy of a natural photographic process of colour. There is known to physicists a mixture of silver-salts so sensitive to light that it is decomposed thereby, and acquires the colour of the rays that fall upon it. By its aid, though at an expense prohibitive to commercial success, a geranium can be reproduced in natural colours, and it may be that some similar composition underlies the skin of these prawns, and undergoes an orderly disarrangement when scattered or evenly diffused and coloured light falls upon it.

But the skin of the prawn is no mere chemical mixture, nor does light act upon it only as on a sensitive plate. It is a highly nervous structure, which is affected both by the sight of the eyes and by the rays that impinge directly upon its surface. The processes of pigment formation and pigment distribution are regulated by the nervous system, acting mainly through the eyes. Permission, as it were, is given or withheld for the development and amount of the several pigments, their close-set or more open texture, and for the pattern which they must follow. As a skilled painter almost unconsciously lays down the groundwork of his sketch, manipulating the purity and mixture of his colours, controlling them by eye, and painting in the high lights against a body colour, so does the eye of the prawn unconsciously supervise the painting of the surrounding scene that unseen hands are rendering, both in relief and colour, upon its own

skin. As there are certain rules of composition in painting, certain old proprieties to be observed, which taste has evolved and custom obeys, so there are certain lines along which the skin-painting of the prawn begins; certain areas along the back and breast and across the body along which the invisible hand first works before filling up the canvas.

In such a fashion the resemblance between the prawn, *Hippolyte*, and its surroundings is produced. Its pigments, primarily organs of nutrition, and still subserving this function, are controlled both from within by the nervous system and from without by the light. So long as the larval *Hippolyte* drifts from place to place through the offshore waters there is no contrast of light and shade that can effect any continuous action; when the tide carries it to the shore it is as a still, colourless, week-old, tiny prawn that it clings to the first holdfast. But once it comes to rest in the submarine forest the contrast of light and shade begins to work a sea change. Its pigments develop, watched over by the eye, encouraged by shade, discouraged by brightness. First along certain tracts that form the easily followed lines of composition, and then filling up the shadows, leaving the high lights to render themselves by untouched canvas, or at most by a sparing use of yellow and white, *Hippolyte* is all unconsciously following the best traditions, and unwittingly, Ulysses-like, making itself a part of all it encounters.

Beyond the power to follow a helpful traditionary

outline by a meagre supply of red pigments, each larva *Hippolyte* issues on the world unaided. It is a born artist, but without any bias that leads it to adopt any style of painting, save that which its first and succeeding stranding-places suggest. Such struggling genius has met with success. Our coast forests are thronged by invisible prawns, seated on bole or branch, and coloured in sympathy therewith. Restfulness is their mark, that receptive attitude in which the cryptic artist receives and embodies the messages of light and shade that fall around him.

Nor is *Hippolyte* the only nor even the best known case of sympathetic colouration.

Among some sea-forests live a multitude of other creatures hardly less harmoniously tinted. There are sea-spiders whose colour varies with the weed upon which they rest; the cousins of the jumping beach-flea, whose bodies reflect their roosting-places down to the minutest detail; the pipe-fish, whose shape, colour and swaying movements make him a part of the sea-grass: the male of which carries the eggs under his body, as though to mimic the flower of the grass. Under the broken lights of sea-tangle young cod, pollack, and a hundred other varieties may be passed unnoticed, so well does their chequered skin harmonise with the light and shadow.

On the sandy shore, away from the rocks, we find a similar avoidance of contrast, a colour sympathy between the sand-dwellers and their resting-place. The dabs and shrimps, the dragonet and goby, the

skate and turbot, the predaceous and the preyed upon, have adopted the livery and tone of the sand. Nor when we leave the sea and follow the rivers do we fail to discover some instances of a similar agreement between the colour of fresh-water animals and their surroundings. In particular the trout, like all fish of sedentary habits, exhibits this sympathetic relation, and becomes light in chalky streams or limestone rivers and dark on a peat bottom or in deep holes.

But that abundance of invisible, and yet boldly coloured animals which the sea possesses is notably absent from fresh water, and if we pass from fresh water to the land we find but few instances, except amongst birds and insects, of that intense colour sympathy which characterises the shore.

Of general unobtrusiveness there is plenty, for shade subdues all colour to itself, and the motley of the ground makes any small object inconspicuous, as a variegated carpet makes a better hiding-place than a self-coloured one. But of that careful rendering of the habitual resting-place which *Hippolyte* has perfected there are far fewer instances as we pass from the sea to the land, and it is only where conditions of a very decisive colour dominate a countryside that we find anything comparable with the clear mark of sandy ground or the bold yet cryptic motley of the rocky coast.

In our own country this can hardly be said to occur, and we turn to the white Arctic regions, the brown deserts, and green tropics to inquire whether bold

deception rules there as in the sea. The white colouring of the polar bear, Arctic fox, of the gulls and terns, seems at first sight an admirable case of sympathy between scenic and animal colouring. But, strictly speaking, white is not a colour so much as the sum

FIG. 30.—Female Orange-tip Butterfly (*Anthocaris cardamines*) on the wing (A) and at rest (B), to show the sympathetic colouring of the under-surface.—(*Copyright, C. D. Head, Dublin.*)

of colours; it is due not to a pigment, but to the covering of the body with a coating of air-bubbles—a froth in the pelage or plumage—that reflects the light and confers additional warmth by acting as a non-conductor. The resemblance, therefore, of many Arctic

animals to the snow and ice may not prove to be one of sympathetic colouration, but to be a part of that more embracing harmony between animals and their surroundings of which the cryptic colour resemblance is a subsidiary and often a negligible factor. The Arctic raven, which is black all the year round, is as sufficiently adapted to its mode of life as the fox or bear, that more habitually live amongst the snow and are so well screened from observation by their white colour.

With the desert it is otherwise. The prevalence of tawny colouring among its beasts and birds, reptiles and insects is a parallel to the speckling of sand-dwelling fish in shallow seas. The lion, no less than the sand-grouse or sand-fly, bears the Ishmaelitish mark—a dun colour, relieved, if at all, by a speckling or shading that melts into the body colour.

Enforced stillness during the heat of the day has given ample opportunity for the working of the soil upon the eyes and skin of desert creatures. The dominant pigment, yellow, of such hoary antiquity and unexpected usefulness, has received a new impetus to its development from the match which it affords to the tone of the ground.

In the forest and field, animal colouration is largely 'pictures of shadow under foliage, with delicate patterns of vegetation and flowers drawn across it.'[1] The partridge, grouse, woodcock, thrush, and snipe show this. Still more strikingly does it appear in

[1] Thayer.

the striping of zebras and forest antelopes, of tigers, the sun-spots of fallow deer, the mottling and striping of squirrels. But such a generalisation can only be grasped by analysis and observation. In the field, as by the sea, two types of sympathetic colouration occur. One, sympathetic *par excellence*, reproduces the adjacent background of those animals that crouch, as moths, caterpillars, goat-suckers, woodcock, partridges (fig. 31). The other, conventional, represents in a bolder manner the more prominent features of their habitual surroundings; to this class belongs the tiger, the zebra, and, in a special manner, the butterflies.

The effectiveness of this animated painting in either class is increased by a mode of shading from top dark to under light, known to artists as effacing gradation; the white breast gives the finishing touch to this result.

The American artist, Mr. Thayer, has pointed out the significance of this gradational colouring. A monochrome, especially a dull monochrome, is the only revealing colouration, and we find few animals (ravens and the rook family; gregarious animals, as sheep, oxen, horses) of this type. If we break up the mass, say by tying white ribbons around a dun pony, a partial effacement is produced, and in rapid movement or in moonlight the broken mass melts into grey as the succession of contrasted belts of colour neutralises their individual effect in crossing the field of vision.

But in a good light such strong, ungraded lines increase the rotundity. The shadow deepens round the

FIG. 31.—Hen Partridge and Young. A good case of sympathetic colouration when seen amongst natural surroundings.—(*From specimens in the Manchester Museum.*)

projecting ridges, the flanks, the belly, and the face, and throws up the animal against the background. A rough clay-bird model is, owing to these lines of rotundity, clearly visible a long way off. But if we balance the shadow by painting those parts white in proportion to the depth of shadow, the result is an effacing gradation, *i.e.* the white breast melting gradually into the flanks. Such a bird is invisible at a few yards.

The same principle that applies to the mass applies also to the shading of separate patches of colour. A striped creature is thus rendered transparent, as it were, when at rest, and a grey, evasive patch when in motion.

But there is no need to search beyond our own country for examples of sympathetic colouration among land animals. Insects carry all their undertakings to a high degree of perfection, and there are no closer resemblances between animals and their surroundings than are to be met with amongst caterpillars. The stick-caterpillars, for example, in form, posture, and colouring resemble so closely the branches or thorns of their food-plant that they can only be distinguished with great difficulty. Clasping a twig with the strong hand, into which the tail is modified, and supporting the head by a transparent girdle, they extend the body at the proper angle, stiff and straight.

Their skin, dark and gnarled, resembles to a nicety the bark of the surrounding twigs; and the resemblance

is further heightened by the stumpy legs of the caterpillar, which recall the irregularities of the twigs. In some cases the colour varies, so that, as in *Hippolyte*, light and dark, plain and variegated forms of the same caterpillar are found, in each case agreeing with the colour of the foliage and the markings that occur upon it. In such sensitive larvæ the same influences are at work in producing the sympathetic colouration as are active in calling forth the agreement between the colour-varieties of the prawn and its weed. In both cases a dim light encourages the development of pigment and the formation of a dark variety; a bright light has the reverse effect; but in the caterpillar the change takes place more slowly, and is less controlled by the influence of sight than in the prawn. In both it is the early stages of development that are chiefly and most rapidly susceptible of modification by the light reflected from their surroundings, but whereas this power persists throughout the life of the prawn, it is lost and the colouration rendered permanent before the caterpillar has attained its full size.

Amongst butterflies and moths there are many instances of the same sympathetic or cryptic colouration. Obvious as these animals are upon the wing, they often disappear as if by magic when they come to rest. The buff-tip moth rests motionless by day upon tree-trunks, and the yellow patch at the tips of its forewings looks precisely like the coloured end of a broken twig. The hair-streaks, which often hover

in a cloud round some ash-tree in May, cannot be distinguished from the leaves when they settle, and fold up their brown wings so as to display the green under-surface.

More impressive still is the resemblance between the leaf-butterflies of India and the dead foliage amidst which they habitually rest. Seen in flight, nothing could be more obvious than the purplish brown wings flapping slowly and uncertainly in the clearings. Seen at rest, nothing distinguishes the insect from the leaves around it. The wings, folded vertically, form a lanceolate area, produced by little tails into an apparent stalk. Down the centre runs a midrib with branches and veinings. In colour the rusty brown of a dead leaf is exactly reproduced, and, as if to carry the resemblance to perfection, the holes and even the worm-eaten appearance of a leaf is given in the butterfly's wings by clear spots and irregular markings. No single detail of form, posture, or marking is lacking to make the agreement complete. The stick and leaf insects of the tropics carry out faithful representations of twigs and green foliage. So close is the resemblance, so motionless the insect, that the very elect of ants are deceived, and fail to discover in the insect actually underfoot any signs of that nourishment they so eagerly search for and so rapidly devour. The mantis, or praying insect, goes beyond all others in its elaboration of floral designs. Its head and three joints are decorated with flat leafy appendages of some bright colour, white or pink,

whilst the rest of the body is dark green. Taking up their position in the full glare of the sun upon some similarly green bush, they draw up the legs so as to produce the illusion of a flower. There they remain motionless for hours, and may be seen week after week in the same position. As the time arrives at which the natural flowers around them fade, the mantis, too, slowly fades in colour, descends the bush, and, like a discoloured bloom, lies to all appearance helpless and fallen.

Spiders are not behind insects in their power of sympathetic colouration. Immobility is emphatically characteristic of them, and has played a considerable part in the production and rendering of the cryptic resemblance.

We may now ask what purpose is served by this widespread sympathy of colouration between the animals of land and sea, and the texture and tinting of their resting-place, or of their associates. The answer that has become almost an unthinking response—protection—is one that came to Darwin as a flash of light, illuminating the meaning of all those devices which seemed otherwise mere freaks. The great naturalist, handling these unrelated facts of nature, saw in the struggle for existence, the search for food, the evasion of enemies, the maintenance of self and of one's family, a strain that tasked the resources of living things and gave a tragic significance to all their life. Unconsciously and intermittently the best adapted, the more flexibly organised were rewarded

by the possession of the earth. By their very enterprise they created competition, as in commerce to-day. By the tendency of all living things to increase in number beyond the means of subsistence the weaker were ousted by the stronger. Those better fitted to endure hunger or lack of air, cold, or heat, those that could escape at such hard times to more genial surroundings and hold their own against its occupants, were favoured, and their offspring again selected by the same process.

Sympathetic colouration, viewed from this standpoint, became a means of concealment from prowling foes, or of lying in wait to surprise and capture unsuspecting prey. The stick-caterpillar, from being a mere freak of nature, became a test-object for a definite experiment ; and Darwin, never satisfied until he had raised a point of view to an assured conclusion, tested the value of his hypothesis by bringing such caterpillars, both singly and on their food-plants, into an aviary. The result was encouraging. The birds greedily devoured the isolated caterpillars and failed to find those on the plants.

More recently the same experiment has been carried out with mantis. Two varieties, brown and green, were chosen, and forty of each variety attached in open ground by a similarly coloured thread to plants of sympathetic and contrasting tints. At the end of a fortnight all those which had been tied to plants of a colour similar to their own were well and vigorous, while those contrasting with their

surroundings had been eaten, chiefly by birds. Again, it was found that where an animal, such as a wasp or white butterfly, was boldly and aggressively coloured it was often rendered comparatively immune to attacks by some odour, taste, or sting. The gooseberry-moth, caterpillar and chrysalis are barred with black and yellow, and display their colours with as much zeal as the wasp, and like it are distasteful. The dominant Danaid butterflies of America and Africa have an acrid taste, that is their defence, and they display by bold, unmistakable colouration the warning of nauseousness. Further, it is by sailing under such colours that a harmless and edible butterfly might gain security. Such is the case. The marvellous instances referred to in Poulton's work (p. 189), of similarity in habit and colour between dominant butterflies and their masquerading associates, are explicable when we realise how instinctive the avoidance of such warning colours has become. Yellow and black, black and white, are danger signals, and give notice of concealed poison. Such new significance thrown upon the warning colouring of animals served to heighten the protective value of sympathetic colouration.

Such results have led observers to seek in protection the entire significance of cryptic colouring: to regard the avoidance of enemies or the near approach of prey as the reason for its existence; whilst to those who are not close observers the general vague resemblance between animals and their surroundings is illogically regarded as explicable for the same

reason. But if we look back on the history of animal colouration as we have attempted to sketch it in the preceding pages, we realise that the pigments of animals are older than the effect they produce, and that the old nutritive, purifying, and respiratory uses of colour are the basis for the more recently evolved protective, warning, or mimetic values of colouration.

Impressive and important as those values are, they could not have been achieved unless there had been a sound constitutional basis to underlie their working. Like some youthful prodigy who startles the world by his violin-playing or reviews, the facts of protection seem created to produce the results that so impress us. But as the artist works through the aid of a constitution that ages of unregarded, serene toil have bequeathed to him, so the mimetic butterfly or prawn has produced its effect through the aid of processes and by the use of materials that its ancestors utilised for their more ancient ways of life.

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CHAPTER IX

THE WELFARE OF THE RACE

THE life-history of an animal or of a plant is not only the record of its maintenance, growth, and development, but also furnishes the seed of the future. The welfare of the race is an inward stimulus to which all beings respond. The endowments of the individual, which have at first sight such an appearance of being purely personal acquisitions and advantages, are in reality of racial value. In animal life the heritage is one of bodily structure and instinctive habit. Man, beyond these, ensues an estate of social and ethical qualities; the maintenance and extension of this kingdom constitutes his most absorbing task and awakens him to the highest influences.

This true affiance is the supreme example of an election between a being and its choice that runs through animal and plant life. It is personified in the higher animals by the love of mates, in which they gather all their gifts to pour them into the lap of the future.

From the lowest to the highest this debt is paid with unwavering response, and is the crowning act of their life. The individual Protozoon literally loses

itself in its offspring, and many of them thereby have never lost an ancestor by death. All their lifetime, until this unique response is made, the immortal animalcule has safeguarded its balance. It has never worked up to its breaking-strain. Like all living things, where their own maintenance and growth are concerned, it has practised reserve. But now, when they are to be reincarnated in their offspring, every consideration is abandoned that should prevent the full inheritance falling to their children.

This bountiful provision for the future is rendered still stronger and healthier by the difficulties that are placed in the way of a suitor gaining the hand of his desired mate.

The difference between mates is apparent, and even striking, in nearly all animals. Agility, beauty, and strength are usually the prerogative of the male. Intent on these possessions, he is the type of the egoist, of the luxurious drone; and it would seem as though, for thousands of such spoilt children, these gifts were sheer vanities, satisfying only the insatiable hunger of their possessor. The splendour of the birds of Paradise are the love-locks of the cock bird. The finest plumes of birds are invariably the ornaments of the male sex, and in most winged and active animals the male appears rather an ornamental than a useful member of society. In many cases his life is one of the airiest and shortest. Though exquisitely formed and sensitive, and with powers of flight that his mate cannot equal, he rarely takes

food, but dances with his fellows, shaking a loose leg over the ground where his partner is hard at work. In such style the male gnats drift over the countryside in short outbursts of marvellous activity, whilst the females alone seek to bite us, haunt our water-butts, and roost in the outhouse. So the male ant and bee drone is but an annual incident in the life of the queen, and almost the whole life of wasps is one of joyful widowhood. Why should such bounty be showered on the drone if it is only to endure for an instant in his mate's sight? Why should he be spared the duty of finding food when her whole life is given to dispensing it?

The answer we can now give is a strange one.

The foolishness of the male is the wisdom of the race, and his ardours, seemingly so self-centred, are an assurance of a test survived and of promised pre-eminence. Disguise the fact as he may, he still is responding to the utmost of his powers to secure the fittest offspring, though with the momentum that is put into the decisive acts of life he is carried past the point of utilitarian necessity in a short outburst of exuberance, as if to conceal the test he has passed.

The most general ordeal is the old courtly tourney; that is, the males do battle in view of those whose favour they strive to win.

With spiders, for instance, the court is held in summer, when the suitors are in their brightest and most vigorous mood. The rivals, after eyeing each other, and then closing in what appears a mortal

combat, ultimately separate, not a limb the worse, though with an understanding, no doubt the original conviction, that one is superior to the other. The victor now performs the most striking advance in order to impress yet more fully his desired mate with a sense of his beauty and prowess. With his forelegs extended upwards and his tail elevated he advances, and then in front of the mate he seeks, performs a frog-dance alternately with his right and left foot, displaying most fully thereby any striking marks or peculiarities that he possesses.

But the lady's choice is not at once made. Usually a second suitor is allowed to perform his approach and love-dance, and only then is the match made.

In such cases the chosen mate is, even to our eyes, the more glorious, and by virtue of such choice the spider obtains a peculiar advantage by at once setting up house. She gains not only the most vigorous mate, but the first choice of site and an early supply of the juiciest flies. The male spider, meantime, having accomplished his fascination, dies in the course of a few days, or falls a victim to the ravenous hunger of his larger mate.

Some such test of beauty, strength, or agility most suitors have to pass. The stag does battle with his fellows through the October nights, and when the strife is over the victor is acknowledged as lord, both by his disappointed rivals and by his herd. The bulls of many animals test their strength by battle. In such fashion many seals are maimed before the strongest

FIG. 32.—Cock Argus Pheasant displaying his plumage.—(*From a specimen in the Manchester Museum.*)

is awarded leadership and wins his mates. The cock birds of our fowls and pheasants choose remote places in the jungle for their contests. The ruffs assemble on the Dutch marshes each spring to perform complex dances and flights before their rivals, and in

FIG. 33.—The Ruff in mating plumage.
(*From a specimen in the Manchester Museum.*)

view of the reeves or hen birds. Only after the fullest display of their plumage, powers of flight and of song is the choice made among them. Indeed, we may say that where the cock bird differs from the hen in plumage, such contrast is an indication of the

fierce competition which the male birds have to engage in before they can claim their mate, or even advance their suit with success.

Among fish the test by battle is, so far as we know, less common; but in such cases it seems probable that either we are not sufficiently familiar with these

FIG. 34.—Black Cock showing off his attractions before the Grey Hen. (*From specimens in the Manchester Museum.*)

creatures to detect the withdrawn and passionate episodes of their lives, or we find reason for believing that another test, not less rigorous, is interposed. There are, however, certain cases amongst fish where a display similar to that of cock birds is executed by the male fish before the females. The dragonet affords a good example. In this common but

inedible fish the male is striped and spotted with blue on a yellow ground, whilst the female is of a mottled, sandy colour. The male's livery, however, is made far more conspicuous by the erection of a large, brightly coloured dorsal fin, and by the rapid movements that display this attire from every point of view. There is no actual battle, but the hen fish delays her choice of mate until the display has been repeated many times.

Amongst insects the powers of the drones are severely tested before their suit is accepted. Types as they are of luxurious living, they act at least once with a strenuousness and passion that no other animal surpasses. Before the queen bee accepts her mate he is but one of a crowd, compelled to make a flight with her and a swarm of attendant workers far up into the sky, and in that ascent one, and one alone, is victorious. What tests he has stood that others failed in we know not; we do know that success means death to him and the massacre of the remaining drones by the workers.

A similar mystery envelops the habits of ants. In their nests few drones are found, and only for a short season. Some warm day in August the entire country is filled with the nuptial swarms that, acting under some influence to which they concertedly respond, rise up in streams from the ground and drift over the countryside, descending on mountains and down chimneys, on house roofs and rivers. On that day the drones pass or fail in their ordeal, and, having

accomplished their descent, victors and vanquished clip off their wings and die.

Butterflies exhibit a similar, though apparently less severe, selection of their mates. Entomologists well know the attractive influence that a single insect will exert over a whole district. By confining a female moth in a wire cage they find that in some strange manner males of that species, even if uncommon or rare in that district, will discover the captive, assemble round her, eagerly vie with one another in striving to win her favour, and, whether by sheer push and vigour, or by some æsthetic consideration, or perhaps by some choice of which we have no conception, one of the competitors is ultimately successful.

It may be urged that such methods are the exception, and that in the majority of cases there is no evidence of such tourneys or of such toilsome routes being performed before the favour of the mate is won. It might be thought that a large number of animals, such as snails and crabs, are incapable of such ardour, and that in any case such a meticulous care for the colour, agility, or strength of the mate would be misdirected energy, since in point of fact any weaklings would be destroyed by natural causes before the mating season. Recent observations have tended, however, to emphasise the severity of the test that most, if not all, male animals undergo; and even if we admit that there are many cases where tourneys are not fought before assent is won, yet that it is not by 'natural causes' that weaklings are weeded out is

evident. There are many groups of animals in which males are scarcer than females. In such cases direct personal competition would be unlikely, and in fact does not, so far as we know, regularly occur. But, nevertheless, a severe though unseen test is applied. Each family at first contains on the average an equal number of the two sexes, and therefore for every male that grows to maturity at least two must perish; that is, the action of natural causes is not the same for both sexes, but falls with unequal emphasis upon the young males. For such diverse creatures as cats, plaice, and hermit-crabs this conclusion has been found to hold good.

The life of animals and of working men agree in this, that, consciously or unconsciously, it is a strife to give their children the best chance. Their response to this spirit takes varied forms, but ultimately it is an answer to the same stimulus, and though it seems to arise within us, it is the spirit of a hive whose boundaries are not limited by the seen or tangible. But the case of animals is heightened by the strenuous selection of mates by whom the welfare of the race can be best advanced. And in this, animals and the lower races of mankind exhibit meticulous care for physical prowess, for on that alone is advance possible.

If we think such considerations below us, the whirligig of time brings in its revenges with cries of deterioration; and we revert to the study of animal life with wonder at the severity of the test and the richness of the reward that such competition exhibits,

as we review each group in its response to the welfare of the race.

The most majestic of these responses is that of

FIG. 35.—Transformation of a groundling Sea-worm (*Nereis*), A, into a migrant of pelagic waters. B, The eyes are enlarged, the paddles more complex and effective.—(*After Quatrefages.*)

migration. Under the stress of a cause not their own, birds and fish assume a new aspect and travel with their mates to far-off, traditional nesting-places. On this journey they behave as creatures possessed.

They endure the extremes of climate on their passage from the rivers to the sea, from the sea to the water-heads. An old memory of the road seems to revive within them, and in following it out they are hardly to be delayed or turned aside. Even the sea-worm leaves its burrow, and, transformed within and without, it then launches itself upon a journey from which it will not return (fig. 35.)

The strange Palolo (fig. 36) of the South Seas, that fills the reefs with its slimy burrows, assumes a new guise at the October and November full moons. Its tail acquires eyes, becomes blue and full of eggs. At the appointed night-time myriads of these fruitful tails separate from their heads, leave the reef, and swim out to sea, where, after discharging their burden, they die or are caught by the natives assembled for the Palolo rising.

The most general method that animals follow in providing for their young is to cast their eggs upon the waters. Heartless and improvident as the act may appear, it is a wiser instinct than we deem.

They seem to realise that the sea is their mother, and that what they cast upon her care shall return as offspring in no long time. Their trust is justified. Movement, oxygen, and ultimately a feeding-ground, are the requirements of the young. They need rocking in order to stimulate their weakly glands, muscles, and nervous control; they need oxygen to maintain their vitality and promote development; and when they are hatched their demand for food is incessant.

These and other needed gifts the waters possess. The open sea rocks them day and night; its even temperature shields them; its foam invigorates and aërates them. Nor has their mother left them without

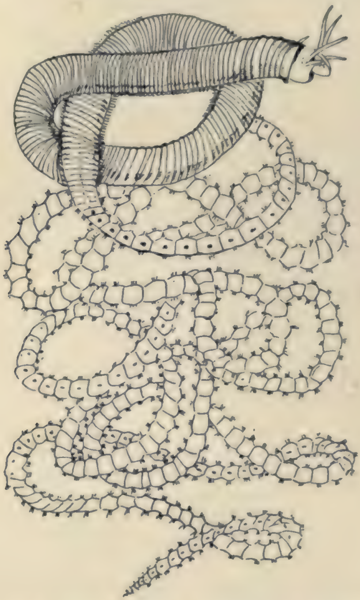

FIG. 36.—The Palolo-worm (*Eunice viridis*) from Samoa. This sea-worm consists of two obvious regions, a head-end bearing tentacles, and a far longer tail-end bearing eye-spots. These two portions part company on the nights of a certain tide in October and November, the tail-end going out to sea, the head-end remaining on the reef and in time regenerating a new tail.—(*After Woodworth.*)

some safeguards. She liberates them in myriads of glassy, invisible droplets from a spot whence the current sets for the shore; she provides them with a float to keep them near the surface; so that when

the young hatch they find themselves drifting into a populous shore-water from which they may gather food without stint; and if on the journey haddock and wolf-fish have fallen upon them, their vast array will endure many such attacks without serious loss. These losses are, indeed, foreseen. At the outset a single

FIG. 37.—Eggs of the Herring fixed to seaweed.
(*From a specimen in the Manchester Museum.*)

family would number perhaps half a million, and if all were to survive the sea would in a few years be a quivering host of one prolific fish. But the chances of the road remove battalions silently, and still leave enough for there to be not only as good, but, fishing apart, as many fish in the sea as ever our histories

record. A second method in which the mother lays her young is that of fixing the eggs to weeds, stones, or the like. The herring dusts them over every object on spawning-ground; the goby glues them to the inside of an old shell; the snail lays her jellied eggs in plates, bands, and coils on any support, and the cuttle-

FIG. 38.—Eggs of the Cuttlefish (*Sepia*).
(*From a specimen in the Manchester Museum.*)

fish fastens her grape-like clusters to the seaweed (figs. 37, 38).

Some gnats form egg-rafts that float on water, others twist ropes that moor the eggs to some fastening. The dogfish hangs its barrow by tendrils to an anchorage; the skate drives her egg-case into moist sand. The perch spins a beadwork of her eggs and spreads it in the reed bed. The frog heaps her

glutinous spawn in the ditch water. With the coming of spring, sea and river appear to break into life. Sea-shore and lake-bank are fringed by these jelly-like nurseries, which seem to spring from the ground or to solidify from the foam. Rarely does any watcher guard this seed. The tide breaks over it, stirs and quickens the latent life. The fitful spring passes over the marshes, now retarding, now hastening, the progress of their future race.

Here and there the mother or her mate jealously guard their treasure from the sight and attacks of intruders. The male goby overturns the sea-shell that his mate has covered with her clutch of eggs and tilts it slightly by burying one end in the sand. Stationing himself at the opening he mounts guard, keeping a look-out, and ceaselessly stirring the water with his tail so as to renew the stream of oxygen which the eggs require. At this season his coat is at its brightest, and responds to the colour of his mood. If excited, the blue spots become more intense and the red shades more vivid. At the approach of an intruder he at once darts out, full of fight. So, too, other fish defend their offspring with a spirit and dash that are unlooked for until we learn what devastation of this spring-laying is wrought by storms, rats, fish, and birds.

Against these destroyers of their broods animals strive to set up defences. Instead of merely fastening their eggs by a slippery jelly, they embed them in a hollow, or even carry them on their own persons. The

lamprey lifts stones with his sucker till a hole has been made in the river-bed, and then the eggs are laid in a sort of nest. The stickleback weaves a neater nest, made of fibres cemented with glue, over which the male hovers. The female pipe-fish makes a nurse of the male. He carries the eggs in a special pocket until they are hatched, and for some days afterwards performs the part of an animated perambulator.

In their efforts to guard their young, animals adopt strange devices. Some frogs wind a string of eggs round their bodies and hind feet; others embed them in a pouch carried between the shoulders; the male of one frog swallows the eggs, and stores them in his cheek pouches, or croaking sacks, until they swim out as tiny tadpoles.

The reptiles bury their eggs deep, and leave them to be hatched by the heat of decomposing vegetation or by the heat of the sun.

Many tropical birds make mounds of rotting leaves over their buried eggs, as though to remind us of their reptilian ancestry. But in the majority of cases birds and insects, true to their high traditions, show the most varied and complicated devices for the safety and benefit of their offspring.

Perhaps the best test of this statement is the record of nests of known birds and insects found by any one observer. Although all the nests of British birds are known, few naturalists, after a lifetime of search, are personally familiar with more than two-thirds of those that occur in this country; and, to take but one

instance showing how easily nests are overlooked, one may quote that of the plover. These birds are systematically robbed of their eggs on many a country-side, and yet the number of green plovers has only lately sensibly diminished. But in countries where the

FIG. 39.—Sand-Martin and Young.
(*From specimens in the Manchester Museum.*)

enemies of birds are more numerous and cunning than in Great Britain, the nesting habits of but a small percentage are known. In tropical America, where the humming-birds are as common as bees on a patch of clover, a naturalist may spend years without

discovering more than one or two kinds of humming-birds' eggs.

If this is true of birds, much more does it hold for insects. The most experienced entomologist, after years of search in a district, will look with some regret on the flies that alight on him, or hover near him, for he knows that he is totally ignorant of the life

FIG. 40.—Nest of Swallow.
(*From a specimen in the Manchester Museum.*)

history of nine out of every ten kinds of the humming life of summer. We must admit, then, that insects and birds place their nests in positions which are usually hard for us to discover. The real extent of their care, however, is only disclosed by intimate study. A few cases only can be briefly considered.

The nests of birds are of the most varied construc-

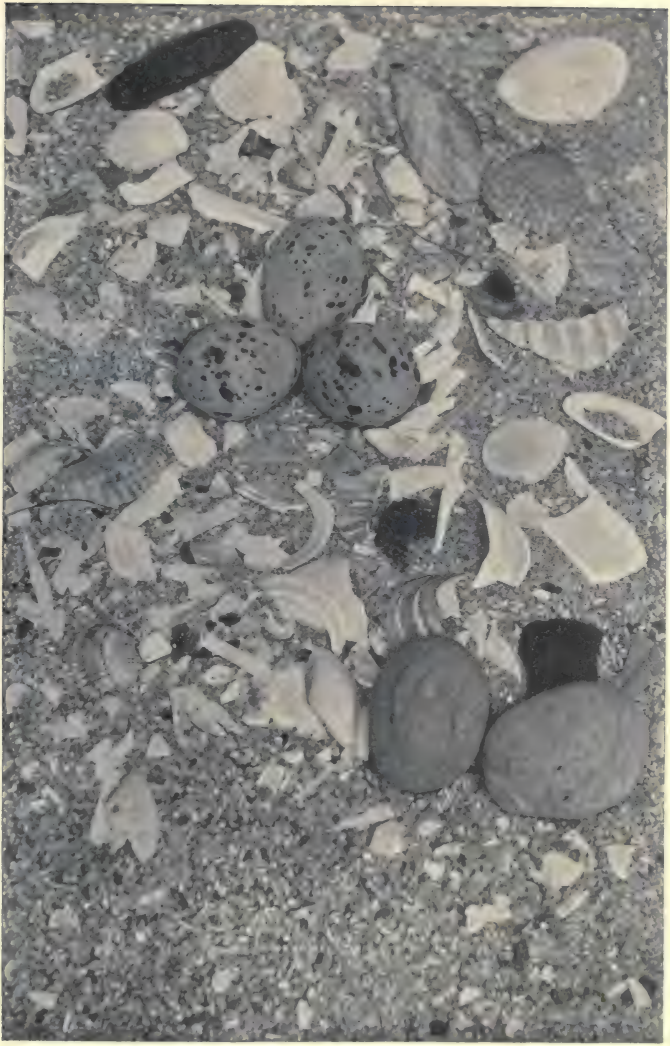

FIG. 41.—Nest of the Little Tern on the shingle just above high-water mark.
(*From specimens in the Manchester Museum.*)

P

tion—from the merest depression in the shingle to the elaborate felt-work of the chaffinch or the pendent house of the ortolan.

Sea-birds make no proper nest. They assemble in vast numbers at a few isolated rocks, grassy cliff slopes, or solitary sand-flats. These they revisit in spring with great punctuality; coming often from great distances, and disappearing when their young have grown capable.

The terns and oyster-catchers lay their eggs only just above high-water mark in little depressions of the shingle or sand. The resemblance of the eggs to pebbles is astonishingly close, both as to shape and colouring (fig. 41).

Gulls assemble on grassy slopes or marshes and lay their eggs in depressions lined with weeds, grass, or leaves. Guillemots lay right on the rock ledges. Puffins utilise rabbit-burrows, and petrels the crannies of rocks.

Wading-birds that spend part of the year at the shore, but nest inland, show little more skill than their purely long-shore relatives in the construction of nurseries. The curlew lays in depressions of the moorland, the sandpipers on the shingle of rivers. Herons make rough nests in trees. Swans collect vast piles of débris without much artifice; ducks and geese are exceptional in lining their nurseries with down.

Powerful and gregarious birds as a rule build clumsy nests. Immunity from enemies seems to render fine weaving unnecessary. Raptorial birds

FIG. 42.—Nest of Skylark.
(*From a specimen in the Manchester Museum.*)

make their eyries on cliffs, crags, or trees, constructing them chiefly of branches and sticks. Pigeons make but a slight foundation of twigs. Rooks adopt a rough lining of roots, and jackdaws improve on this by lining their large nest, hidden in some hole, with fur.

With small birds, whether solitary or colonial, the case is different. Their choice of site is wide, and the degree of secrecy and skill employed in the making is most varied. The nest is usually of the open-topped type, and generally consists of an outer layer of coarse material lined with moss, feathers, or some fine and non-conducting material. Both sexes assist in its construction, and employ their bills and feet in doing so with a skill and assiduity that reach their maximum in the exquisitely finished handiwork of the titmouse (fig. 43) and the chaffinch.

The need for this greater skill in constructing and concealing the nests of small birds seems to lie not only in the defencelessness of the artificers, but in a consideration that affects their young. Nests are formed, not merely to surround and screen the nestlings, but to enable the incubating heat of the sitting bird to be concentrated on the eggs. Now the size of an animal is directly related to its power of retaining heat; for with two creatures, one double the weight of the other but of equal proportionate powers of heat production, the heat produced will be as eight to one, whereas the loss of heat in proportion to weight, that is, roughly, in proportion to production, will be determined by the amount of body surface from which heat is lost, that

FIG. 43.—Nest of Long-tailed Tit-mouse.
(*From specimens in the Manchester Museum.*)

is, as four to one. In other words, a small bird tends to lose its heat at a higher rate than a large one, and in order to maintain the same degree of heat, either

FIG. 44.—Young Cuckoo in Nest of Titlark.
(*From specimens in the Manchester Museum.*)

its productiveness has to be increased or loss of heat checked. The great voracity of small birds contributes to maintain the production of heat, and in order to concentrate this upon the eggs a non-conducting lining and hollow shape is given to the nest. By this means the development of the egg is ensured, and the nestlings are protected until they have developed a heat mechanism sufficiently strong and pliable to enable them to lead a free life, at least during the warmth of the day. A similar principle underlies the nests of mammals, of which that of the harvest mouse is perhaps the best example (fig. 45).

FIG. 45.—Harvest Mouse and Nest. (*From a specimen in the Manchester Museum.*)

That vast collection of artificers which we name insect, exhibits in the care of its young, as in every other pursuit,

the most varied methods; but in their response to the stimulus of race-maintenance, more than in any other performances, insects of the higher classes exhibit a dominant interest. They have brought their several works to high degree of finish, and exercise in doing it such unwearied devotion and skilled instinct as to furnish us with a theme that exhausts our astonishment as it stimulates our wonder. In the choice of nesting site, and the construction of the building, in the storage of suitable food and its replenishment, in the division of labour and response to a communal spirit, the social insects have undoubtedly worked out a full and successful scheme of life. There is perhaps no other society where individual interests are so subordinated—now in one direction, now in another—at the command of a genius that seems to dominate the whole and to declare how the welfare of the race is to be served.

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CHAPTER X

THE LIFE-HISTORIES OF INSECTS

Of all the impressive actions that insect life presents, those connected with the welfare of their young and with their life-history are the most important, and in fact it is largely by their other-worldliness that the group has risen from its obscure beginnings and poor relations—the spring-tails, silver-fish, and centipedes—to range after range of dominance in the kingdoms of the air. Beyond the usual demands for racial welfare, such as we meet with in many other highly organised and aerial creatures—spiders and birds, for example, there has evidently been, in the case of insects, some factor at work which has led to this elaboration of nurseries, this preparation of special foods, this sunlit devotion to the needs of a progeny that its mother may never see.

Such a factor we may see in the influence of climate. Insects are border folk. They are the offspring of earth and air. Great as are their powers of adaptation, they have failed to adjust and maintain the temperature of the body without direct reference to that of their surroundings. Hence their vitality rises and falls with the thermometer, and the more exaltedly

they rise in the scale of insect-life the more, rather than less, sensitive do they become. A frost that kills bees like flies passes lightly over the spring-tail, safe in the close embrace of his warm, ancient earth. Against the onset and rigour of the cold insects have no protection, save to bury themselves in the ground. From the parching influence of continued dry heat they have also few means of escape, so that in tropical and temperate climates there is a period when insect life is partially exterminated. But with the next rains or the coming of spring the hospitable period ensues when sap, pollen, honey, and juicy leaves provide a feast. Hence for insects to pass, even in a winter sleep, through the lean period so as to reach the fat season, is a consideration of supreme importance; and to utilise the new growth for the development of as many fresh broods as the summer permits, is of hardly less pressing importance. It is this oscillation from plenty to poverty which drives insects to such multitudinous devices, and maintains in their advanced sections of society such a high degree and standard of activity devoted to racial ends.

We may commence the cycle at the season of spring. From crannies and underground hiding-places there emerges a remnant of the summer's host; a few butterflies have survived the winter in barns and lofts; caterpillars have hibernated in moss, that resort of the frost-hunted; many beetles and ants have slept in the ground, a queen bee and queen

wasp have here and there lain moribund under clods of earth. From caves and hollow trees the few surviving flies of the huge summer legion creep into the outer air. Ensconced between bark and trunk, among bud scales and in the ground itself, are the imperishable eggs of green-fly and scale-insect, which no frost can kill and no mould injure. These hatch at the coming of spring and provide a new generation of aphides and coccidæ which fatten on the opening buds, and from imperceptible beginnings increase their coming with an acceleration that is ultimately to raise the rate of increase to one that the vibration of light alone can parallel. In the water there are few signs of summer's abundance. As on land, a last stand has been made by a few water-beetles, with perhaps may-fly, dragon-fly, or caddis-fly larvæ here and there; but the seed that is to flower out into wriggling plenty is at present an inert, encased egg left by dragon-fly, alder-fly, or stone-fly in the unstirring mud or on the water weeds.

With the onset of warmth these scattered centres of suspended animation resume or commence their activity. The hive-bees that have clung together for warmth make their cleansing flight; the solitary burrowers drill, with teeth and claws, holes in the sandy bank; wasps select their sites and begin to work up wood-chippings for the nest; ants creep from the deeper earth to the surface and under cover reconstruct their city; beetles scavenge the roads and meadows, rifle the early blossoms and leaf buds, or scour the

pond-weeds; flies gain strength to travel where the rising sap and filling nectaries, the warm blood of some livestock or some less attractive nutriment, may give them site and substance for their own needs and those of their offspring.

Week by week the life of the pond increases as the dormant eggs therein hatch into the larvæ of hovering flies, and as the few hibernating aquatic larvæ become transformed into the first dragon-flies of the year. Then, as the fluttering, humming, and creeping life is resumed, its first impulse is to provide, not for itself, but for that which is to come, to find a place where the young may be laid so as to reap the first-fruits of the spring; for now there is a new market and but few competitors, and presently the blooms will be gone, the enemies many, and the strife fierce.

Thus the first spring brood makes its several election of nesting-places. By some sense of smell, and yet unexplained instinct, the butterflies and moths, winter-worn or spring-fresh from their pupal cases, deposit their eggs in little batches on or near the food plant that the caterpillar needs. Each egg is a minute, impermeable, sculptured vase, completely enclosed in which is the germ of the future caterpillar. In a week it will emerge gifted with as great a preference for one plant rather than another, as though it had a large experience and a matured decisiveness. Such narrow taste in a new-born creature is, however, the rule. As milk is the best and most acceptable first food for our race, so, from the simplest worm up-

wards, there is one diet on which the development of each creature is dependent, and the higher in the scale we ascend the more specialised as a rule does that nutriment become. When we add to this exigent taste the delicacy of new-born animals, and the penetration of enemies, we see that the choice of nursery is ruled by conditions that confine success in promoting the existence and welfare of each race to a comparatively narrow line of conduct.

This stringency is, however, a penalty paid for a high and modern place in the insect world. The lower insects, and those of very ancient origin, have more latitude. Nearer than recent conquerors to their ancient home, the soil, the straight-winged insects, field cockroaches, grasshoppers, and crickets lay their eggs in the ground.

When the young emerge, not as grub-like caterpillars, which is rather a sign of a recent than of an old family, but as little six-legged miniatures of their parents, these young aristocrats exercise their taste for almost any destructive work, under cover of darkness—wood-carving, root-cropping, or mould-eating. Thus, between the old and the new insects, there is a difference from the commencement of life. The old families have to work for their living on coarse fare, the new are provided for and live delicately.

It is, however, only by the advantages which such forcing gives that the newer families of insects have gained the command of new stations. If they have not the strength, adaptability, and ordered tradition

of the locust, the dragon-fly, the clothes-moth, and certain beetles which represent the *fin fleur* of insect peerage, then new-comers must command success by other means, and these they employ from the first moment of their children's lives. By giving their young a start in instinct, in position, in surroundings, they do much. But initial advantages such as these are not enough to maintain the struggle, limited as it is to a few months each year. The spurt must be followed up by rapid growth to maturity, and by a succession of broods with powers of securing new stations, and so immolating themselves in the aggrandisement of the race.

It is with this hurly-burly in mind that we appreciate the contrast of the fly, which grows up in ten days, with the locust, which leisurely pursues its childhood for a year or more. It is this competition for the success of the family within the limits and by the gifts of summer, that has raised bread-winning to such a high art, so diversely followed, according to the age traditions and genius of the different orders of insects.

The earliest traditions of insect history, unlike those of most groups of the lower animals, point to a terrestrial, air-breathing, mould-nourished way of life. Between the infantile and adult habits there was no great difference. Lovers of dimness, their favourite resting-place was in the rich earth, where young and old found nourishment in abundance, shelter, and means of escape from animate and inanimate ravages. Their movements consisted in only short runs or sudden

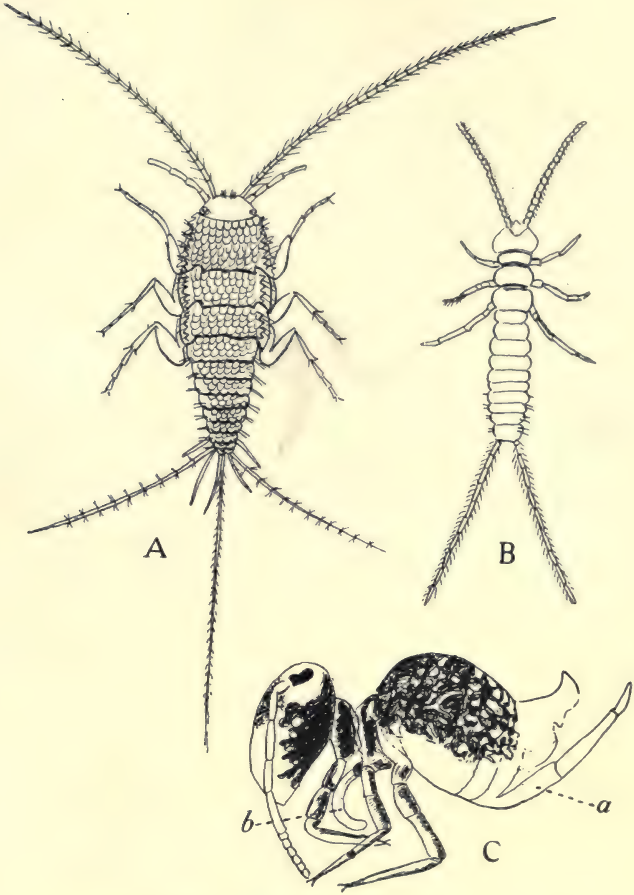

FIG. 46.—Some Primitive Insects.

A, 'Silver-Fish,' *Lepisma*, found in kitchens.—(*After Buffon.*) B, *Campodea*, a small white antique insect found under stones. C, *Sminthurus*, a member of the order *Collembola*, provided with a spring (*a*) and a curious ventral gland (*b*). It occurs on grass, the surface of water, and sometimes on tomato-houses.

leaps, executed by the six legs or spring-joint of the tail (fig. 46, C, *a*), for flight is not yet known, and their shoulders are destitute of wings. Such creatures are everywhere abundant, but, like all old families, their influence is less seen than felt. They live in retirement—every stone and log conceals them ; leaf-strewn hollows, banks of moss, kitchen hearths, and gardens are equally their resort. From Europe to Tasmania, on lowlands and highlands, on snow slopes and in glacier water, there is hardly a station where they may not be found. Their colours are for the most part sombre ; dark blue and brown chiefly prevail. The silver-fish of our hearth-stones is of exceptional brilliance, and contrasts with its dun-coloured relative of the coast and uplands. Their eggs are laid in the earth, and out of them issue miniatures of the parent, which grow to greater likeness by insensible gradations and increments of strength.

The straight-winged insects are of immense antiquity. They have retained their dominant position by their hold on the earth and grasp of the air. In every respect the tribe of grasshoppers, locusts, and cockroaches shows an immense advance on their predecessors in their two pairs of wings and powers of flight, in the strength of their legs and jaws. They have come out into the air and sunshine, and scrape their fiddles and leap and fly in the exuberance of their energy. Nor is their colour unsuited to the mood. Grasshoppers catch from the grass something of its green ; from the leaves some touch of their red ;

whilst the burgling, nocturnal crickets and cockroaches are appropriately dusky.

The provisions of these Orthoptera for the welfare of their children are of the simplest. Their eggs are laid in the soil or in dark corners, and are provided with yolk and a tough covering. In from fifty to a hundred days the young emerge. By the aid of a special swelling in their neck they break the wall of their

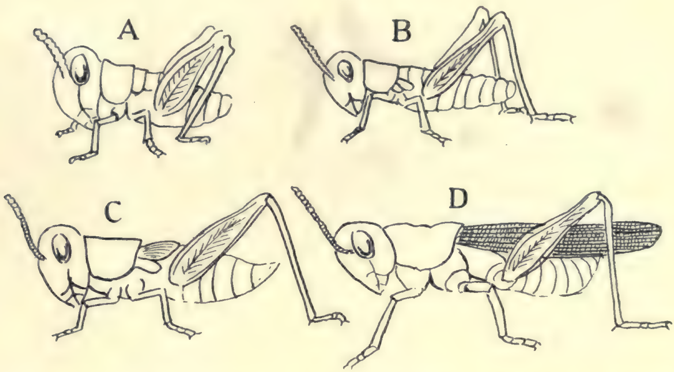

FIG. 47.—The development of a Grasshopper, showing the gradual evolution of the wings.—(*From Packard's 'Text-Book of Entomology.' By permission of the Macmillan Co., New York.*)

prison, and once set free in the soil they commence to nibble the roots and moulds that surround them. In appearance, as we have said, they are miniatures of their parents, except in colour and winglessness. Developed in the dark, these little grasshoppers or crickets emerge as pale, minute creatures, which for two or more months will slowly grow, bud out wings from their shoulders, and fly at intervals in the warmth

and sunshine, to harden and exercise their limbs. At regular periods their inflexible skin has to be removed to allow of growth, and a covering one size larger replaces the old coat. As the rate of growth in insects, as in all animals, is fastest at the beginning of life and slows down later on, the skin has to be frequently changed at first, and at longer periods subsequently. We rarely appreciate with what difficulty and danger the process is accompanied. The outer skin is a continuous envelope, softened only at the joints of the body and limbs. Not only are all the visible parts encased by this covering, but the lining of the mouth and many internal parts are formed by infoldings of this skin. Hence an insect has to sever this intimate union as well as to slip out of its external casing. It must strip its inside and its outside of their protecting envelopes, and the wrench tests all its strength.

The first act is a rent in the outer garment between the thorax and head, made by forcibly filling the vesicle in the neck until it breaks. Humped up thus, the struggle goes on till the head and neck, with all their appendages, are free. To pull off a jersey is simple compared with the act of pulling away the eyes, the antennæ, the jaws, the legs, the mouth, and stomach from their encasing skin. Any holdfast to which the old skin can be hooked and then pulled off is made use of, and at this time the use of many projections on the body is first discovered. The legs gratefully cling to the tail if thereby they may pull themselves out of their casing; and so with much

effort the forepart of the body is drawn out of its old envelope. Then follows the disclosure of the abdomen, and the old skin is wholly discarded. The young grasshopper is now soft and helpless. Its new skin, more brilliant than the old one, is wet; its muscles fatigued. For a while, therefore, it lies waiting for its heart-beat to become steady, its skin to harden, and its muscles to resume their tone.

A comparison of the old skin with the new one reveals certain differences between the two. Not only are the colours brighter than before, but rudiments of wings are now disclosed. At each successive moult of the grasshopper both the size of the animal and of the wings increase, until, at the final change, the spread of wing can sustain the body for short flights. The development is therefore a gradual one. Each stage has been gradually accumulating under the covering of the previous one. As there is no violent break in structural development, so there is no change of habits till the first flight is made. Old and young live under similar conditions, and probably upon the same vegetarian diet. The wings are chiefly used to carry the grasshoppers into new districts where they may found fresh colonies.

The life-history of the grasshopper is one typical of the vast and ancient order to which it belongs. This order—the Orthoptera—is to other insects what the rodents are to other mammals. They share our dark corners and produce with mice and rats; they gnaw the herbage with the field mice and voles. They

burrow in the ground like rabbits to bring forth their young, and share the desert and veldt with the jerboa and the Cape hare. Their development is a gradual one, with no long period of exposed unprotected state of helplessness. They begin life as relatively large heavily yolked eggs hidden in the ground. They hatch as strong insects capable of biting and assimilating the leafy food that surrounds them. They grow from strength to strength without the internal strain of adolescent change or the outer stress of metamorphosis. They emerge upon the sunlit or moonlit meadow which has fattened them, and either in its soil or in the ground of some distant country they provide for the welfare of the race.

The Dragon-fly.—If the ancient orthopterous insects form the type of dominant herbivorous groundlings that grow by increments and only momentarily fly from blade to blade, the dragon-fly is equally the example of the ancient carnivore that grows in the water and then lives on the wing. Flight, which to a grasshopper is a temporary exertion or a colonising movement, is the natural habit of the dragon-fly and is carried to a degree of perfection that is reached by few other animals. So aerial has the dragon-fly become that it can no longer walk, and only uses its legs for holding prey or for perching. This hawk-like flight involves the renewal of a light food at frequent intervals, and the structure of the dragon-fly is a superb example of the means of obtaining the juices of insects. Its whole aspect is that of a dominant

FIG. 48.—The life-history of a Dragon-fly (*Leucorhinia glacialis*). The aquatic larva is resting on a submerged stem. The last larval stage is creeping up out of the water.—(*After Needham. From New York State Museum Bulletin*, 1901.)

race. Its large size and powerful wings give it the command of a wide range of country, and the capacity to migrate across narrow seas. Its colouring is vivid and metallic. The mobility of its head and the huge eyes that almost enclose the head enable the dragon-fly to take note of objects on all sides, and to seize its prey from any position. The six legs enclose the prey. The jaws rapidly dismember a stricken fly, the juices of which are sucked through the minute mouth. The dragon-fly is one of the few old groups of animals that are conspicuous. Its ancestry reaches back to remote ages, and there is reason to believe that the swamps of the coal-measures were haunted by raptorial dragon-flies similar to those that to-day quarter the river-courses in most parts of the world. This long descent is evinced by its vitality, for the head severed from the tail will continue to eat as heartily as before.

The prelude to this sunlit active life is passed quietly and inconspicuously under water. The oval eggs are dropped casually into a pond or marsh, or even a water-holding leaf, and give rise in the course of weeks to a grotesque creature about a tenth of an inch long. It is just visible to the eye as a brown wingless animal. The head is flat and furnished with minute eyes. The six legs are used for slowly exploring the muddy bottom, and the tail has the curious faculty of inhaling and expelling draughts of water for the double purpose of supplying oxygen to the tissues and of making sudden springing jumps.

Almost the first act of this 'nymph' is to cast its

first larval skin, and when that difficulty is overcome the special instincts of its kind manifest themselves. From first to last all are carnivorous, but adopt various ways of overcoming their prey. The nymphs of some dragon-flies conceal their body in the mud, under the surface of which they make their way by slow puffs of the tail, and then dart out upon some passing beetle, larva, or worm. Others lie motionless among the weeds, with the colouring of which their own agrees, and spring out from cover upon their prey. A few bolder forms make no concealment, but pace up and down seeking for provender.

These nymphs are provided with a singular weapon for catching prey. This is the 'mask' or under-lip, which is greatly elongated and doubled back by a hinge-joint until it almost touches the forelegs. To its free end is hinged a pair of curved opposable teeth, and when the desired prey is yet an arm's length off, this long arm is smartly extended with a sudden jerk, the prey is seized by the teeth, and whipped back into the safe grip of the other jaws.

After the third or fourth moult, buds of the two pairs of wings appear on the thorax, and grow steadily larger at each stage, the eyes increase in size, and the nymph prepares for its final change. It climbs up a support, fills its tracheæ with atmospheric air, and shovels off its investment. The brilliant fly emerges, and in a moment develops all the power of flight it will ever display.

May-flies.—Among the mazy dancing insects that haunt rivers, some relatives of the dragon-fly are well

known to the angler. The ephemeral may-flies hover thick as snowflakes for the short afternoon that rounds their winged life. The stone-fly flutters to a warm resting-place, whisking its long tails. The alder-fly rouses the fish to feast on the windfalls that every puff provides. These gauzy hoverers are rising from the water. The fringing weeds are hung with their discarded suits. The river-bed has been crowded for the past year with their creeping nymphs. (Frontispiece.)

The life-history of may-flies or ephemeridæ lasts from one to three years. The oval eggs are laid on the surface of the water by the swarms of flies that hover over a river for a day or two. They sink to the bottom and become attached by anchoring threads to some holdfast. After an interval these eggs give rise to shrimp-like larvæ, with two or three tail-filaments, and just as there are many kinds of ephemeræ, so the larvæ are of different form and varying habits. All, however, undergo many moults, acquire several pairs of leaf-like gills, and pass by gentle gradations into the winged state. Their adaptations to different modes of life are of much interest. Some are burrowers, and feed upon finely divided organic matter. These possess a long body, a small head, and dig with their forelegs. The six pairs of feathery gills are kept incessantly moving, and each contains a branched air-tube as well as filamentous blood-vessels. The air in these breathing-tubes is, however, not drawn into them from the atmosphere, since there are no inhalant openings from the surface, and it must therefore

accumulate by diffusion. Such larvæ are very common in ponds and slowly moving streams. A second kind of larva is one adapted to live in the rapid streams of upland districts. The body and its appendages are broad and flattened, enabling these species to withstand or evade the current by clinging to stones whilst utilising it for respiration. These larvæ are carnivorous and make no burrows. A third larval form is the swimming one, such as that of the common Chlœon, found in pools and small streams. The tail-filaments are fringed with hairs, and form an effective tail-fin. The gill-plates have no filaments. Lastly, there are creeping forms of may-fly larvæ which live in running water on muddy ground and cover their gills by large leaflets. Their body is encased in a layer of mud imbedded in the hairy skin, and under cover of this disguise these larvæ strike down their prey.

When the larvæ are full grown they quit their burrows or the river-bed, and make their way to the surface of the water. Here a rapid metamorphosis occurs, and from each larva a winged fly suddenly darts away. The gills are shed, the jaws, feet, and tail-filaments are modified, and the eye exchanged for a many-faceted compound eye, and the single or double pair of wings is suddenly expanded. The may-fly, however, settles immediately after emergence, and again, in a twinkling, casts a second transparent skin which covers the whole body. This epiphany comes upon thousands of ephemeræ simultaneously, and in

many districts the whole local population of one or two year old may-fly larvæ undergoes its transformation in two or three successive afternoons.

The More Complex Life-histories—Metamorphosis

A distinctive feature of the life-histories we have described is the gradual evolution of the fly. The assumption of the last phase coincides with the completed formation of wings and the display of flight. Only in its last phase is the organism sometimes transformed in outward appearance for aerial life. This gradational life-history is one of great antiquity, and the insects that exhibit it come of an old stock. Young and old are in close touch with the primitive life of earth and water, feeding on moulds and herbage, devouring the flesh of simple organisms or the mingled decay of organic life. The most primitive of all modern insects remain groundlings; but the necessity for disseminating their eggs and colonising new districts has acted as a spur which has driven the adult insect of other orders to become a fly. In its simpler forms this power does not involve any great change of habit, but for its perfection flight requires the nicest adaptation. The changes needful to this end are therefore worked out towards the close of the earlier and more sedentary phase of life, and involve a less or more complete transformation of the organism—less as the time is long and the preparation gradual, more complete as the life is shortened and the

broods are hurried on to enjoy the summer, to spread and increase its abounding life. In this way the life-history of the modern insects become divided into periods characterised by adaptive structural features. The earlier period is one of growth, the last is one of active colonisation, and as these functions become mutually incompatible, a gradual change from the earlier nymph to the later fly has been abandoned. An intermediate period is introduced during which the transition is effected. Aided by this, the earlier or nymph stage can now more freely adapt itself to circumstances that favour growth, the fly can acquire new combinations of structure and instinct that will aid the spread and welfare of its race, whilst the transition state itself becomes adapted to that protection which it increasingly needs as it becomes the seat of that complex remoulding of the old traditional life to meet fully the new activity. To the insect in this transitional period the term *pupa* is applied.

Caddis-flies.—The caddis (or hairy-winged) flies offer a convenient example of this more complex life-history. These insects abound near rivers and ponds, and are not widely different from certain small moths, though their four wings are provided with hairs instead of with scales. The eggs are laid in or near water, though occasionally far from any stream or pond. The larvæ, well known as caddis-worms, have 'something of that versatility which characterises the whole class of insects.'[1] The great majority of

[1] Miall, *Natural History of Aquatic Insects*, p. 255.

species form movable cases of the most varied materials. Others bind portions of the river-bed together into a burrow or fixed case, which they quit at pleasure. Some are adapted to still water, others to rapids. A few inhabit brackish water or are marine, and at least one is terrestrial and lives in moss at the base of trees.

The caddis-worm or larva may be easily exposed by passing a pin through the harder end of its case, and it is then seen to be a fleshy creature provided with a head, a thorax bearing six legs and four tufts of bristles, and an abdomen of nine segments, the first and last of which carry peculiar processes, whilst the intermediate segments bear filamentous gills. The last pair of processes are hooked, and grip the sheath or case so firmly as to remind one of the hermit crab which clings to its shell by the hooked tip of its tail. The first abdominal processes are three in number, though not all alike, since the middle one can be protruded or withdrawn whilst the others are fixed by minute hooks into the sides of the case. The use of these processes has been determined by extracting larvæ and giving them a transparent substance (mica) out of which to form a new case. When this is done the abdomen is seen to be fixed in front and to undulate gently for the greater part of its length. It is, in fact, drawing in a current of water that flows over its body and through the case, thus aerating the gills.

The manufacture of the case is a process full of interest and of possibilities of experiment. In its shape, materials, and construction the different species

of caddis-flies exhibit distinctive workmanship. Leaves and sticks, stones and shells, or sand alone, are worked up into cylindrical or curved tubes. The binding material is silk spun from the silk-glands and worked up by the lower lip of the animal. Some larvæ that live in running water spin a roomy case of silk open at each end and moored to surrounding objects by threads. These threads form a snare in which other larvæ become entangled. The caddis, aroused by the increased agitation, emerges from its retreats and kills its prey.

When the time of pupation arrives, the caddis larva proceeds to add further protective measures. It remains in the case, but closes up the two ends with plates of silk ; or it may block up the openings with stones, or construct a shorter case of stones to replace a leafy one, or other more complex contrivances. Within this shelter the larval skin is shed by the following day, and the pupa appears. In this stage the wings, legs, antennæ, eyes, and other organs of the fly are visible, since they lie free and are not glued down, as in the pupæ of most moths. But the body is not at rest. It still carries out the undulating breathing movement that we have seen in the larva, and it still possesses the gills. In addition to these processes the pupa has a pair of strong-toothed hooks, or mandibles, quite different from those of the larva. With these hooks the pupa works its way out of the stony case that has protected it and either floats, swims, or crawls to the surface of the water, out of

which it creeps over stones or plants. The pupal skin now splits, and the fly emerges.

Beetles.—The life-histories of beetles offer another simple example of metamorphosis. They fall into the three epochs of larval, pupal, and adult existence. It is with some surprise that we find in this order the gradational mode of evolution superseded by this abrupter succession of events; for beetles bear the marks of antiquity. They are in close touch with the soil, their food consists largely of moulds and of the organic substances, animal and vegetal, on which fungi are flourishing. The majority are cryptic or crepuscular, and only the more modified forms feed on sap, pollen, or nectar between their flights in the sun. But though the life-history of beetles has a pupal stage of preparation for the life of maturity, it is marked by a leisureliness that recalls the long immaturity of the grasshopper and the dragon-fly. The cockchafer is three years old when it emerges in summer, some ground-beetles have an equally long larval life, and stag-beetles six years. Moreover, the larvæ show few of those special adaptations that make the caterpillars so attractive. They are usually six-legged, spindle-shaped organisms, with powerful jaws, but with no gracefulness of form or movement. Their obscure life is reflected in their dull or fleshy tints. They live for the most part on roots, fungi, wood, or on other animals, and are among the scavengers of the earth. The dor-beetles and the related scarabs dig holes and provision the burrow for their young.

The burying beetles are no disinterested workers, but inter animals to serve as food for their larvæ. Others again are root-croppers, such as the skip-jacks, whose larvæ—the wireworms—devastate grassland; and again other families of beetles, such as the weevils, destroy grain, root-crops, and vegetables. But even this sombre order has its more adventurous careers. The oil-beetles (Meloe), whose stout blue form may often be seen sunning itself on grassy banks in early spring, has passed through a life-history of unusually

FIG. 49.—Elaters or Skipjack Beetles (*b* male, *c* female) and their larva the Wireworm (*a*).—(*From specimens in the Manchester Museum.*)

full incident. It proceeds from one of a large batch of eggs laid in a flowery dry bank. Out of these eggs there hatch a multitude of minute active yellow six-legged larvæ. This immense family climb the grass and flower stalks, covering them as with a yellow down. Presently a bee—one of the many early spring burrowers, *Anthophora*—will chance to settle near them, and with a concerted spring a detachment of the Meloe-larvæ will catch hold of its hairs and ride on till the *Anthophora* visits its burrow. Once inside,

they are carried down the dark shaft and into the chambers where the bee's eggs are laid and the pollen stored. Here they alight, wait until an egg is laid, and then fight for its possession. One obtains a hold, a second attacks the first and kills him, only to find that a third is at work. Finally one alone survives, and then the real tragedy begins. These Meloe larvæ require the entire yolk of a bee egg in order to reach the next phase of their life-history. No substitute, nothing less than this, gives the needful stimulus for further development. The survivor, successful up to this point, now finds only a partial egg. This he devours, but the amount of yolk is just too little. He fails to achieve transformation, and joins that crowd of failures to which he has despatched so many of his fellows. Few indeed of the yellow 'triungulins' that ride as so many Pucks on the bee's back survive the family quarrel. But to those that do, a strange experience is allotted. They become transformed into larvæ of another type, no longer active and restless, but swollen and buoyant. Their diet changes, and for forty days they swim in the stores of honey which *Anthophora* laid up for her larvæ. Having devoured this, the Meloe-grub pupates and in from one to several months issues as a perfect beetle.

Butterflies.—The life-histories of moths and butterflies are to those of beetles as modern events to those of ancient times. They are passed under conditions more familiar to us than those of beetle life, often, indeed, in the full light of the sun, and amidst the most

complex and recent of plants. The full-grown animals are familiar to us, their caterpillars and chrysalids are common objects. Such intercourse argues a successful and complex career. Butterflies are nicely adapted for their sunny life. They are emancipated from touch with the soil, the old coarse diet, and the primitive conditions of life. Their structure is one of the most complex organisation, and is sustained by a delicate light nutritious drink. Their colours and form bear witness to a complexity of life far removed from that of the insects we have so far reviewed.

If the butterfly and hawk-moth are specialised in structure and habits, their larval stage has in its way adopted a far more complex life than is led by the young of primitive insects. They feed no longer on the fungi and mould-haunted provender, the tough wood or fibre that nourished their cryptic and simpler forerunners, but devour the juicy leaf of the more recently evolved herbs and vegetables. They have acquired decoration of form and colour, activity of movement, measures of protection, and a nicety of adjustment between their needs and the good or evil chances of their surroundings that finds expression in their choice of food plant, powers of hibernation, and capacity for social life.

The transition from this caterpillar life organised for rapid growth to the state of flight has itself become subjected to profounder changes than those that affect the pupæ of the caddis or the beetle. The chrysalis is no longer always buried in the earth, but

slung up by a silken hammock to a wall or a bent. The play of light and shadow is reflected in its colours, and the play of more profound and active agencies than these is remoulding within it the body of the caterpillar into that delicately poised organism the butterfly.

The life-history of the common cabbage-white butterfly will give point and example to these statements. The minute, vase-like, exquisitely sculptured eggs are laid by the female on the cabbage leaves or other cruciferous plants. In the course of a week the young caterpillar emerges. Its worm-like body is composed of a head, thorax, and abdomen. The head carries powerful jaws inserted between the upper and nether lips, rudiments of antennæ, and a few simple eyes. The thorax consists of three segments, each of which carries a pair of stumpy legs. The abdomen, divided into nine segments, possesses clasping feet on the last four of them. The colour is a whitish tinge speckled with grey, and from the third thoracic segment to the last abdominal one, paired black marks indicate the breathing holes or spiracles. Movement consists of a series of muscular waves passing from behind forwards, aided by strides of the fore- and hind-feet.

The first decisive act of the young larva is to cast its skin. A crack appears along its back, and the moult is done by peeling off the skin inside out. There is now room for expansion, and this the caterpillar seeks to fill first with its own husk and then with the

A C

B D

E F G

FIG. 50.—Development and Parasites of the large Cabbage-white Butterfly: A, a pill-box, the white specks within which are the eggs; B, the full-grown larva; C, the male insect; D, the female; E, the pupæ showing the wings and appendages; F and G, Ichneumon parasites of the caterpillar.—(*From specimens in the Manchester Museum.*)

surface-layers of the leaf on which it rests. On the chlorophyll, starch, and other elements of this diet, it rapidly grows and adds reserves of fat to accumulate beyond its present needs. Moult follows moult with increasing size, and the spines that project from its surface find their office is assisting the process by preventing the old skin from slipping back as it is peeled off the new one. At the sixth moult a change of form occurs. Knobs and ridges that had been moulded under the skin now appear glued down on to the head and thorax. In these projections we can recognise the eyes, antennæ, proboscis, legs, and wings of the butterfly. When these appear the caterpillar is full fed. Bearing the marks of the perfect insect, it now assumes the shelter of a wall-coping or other crevice, to the sides of which it proceeds to attach itself by means of a silken hammock. To spin this support, the larva emits a drop of liquid silk from its mouth, bends its head back under its body, and works from side to side fastening the thread at two points opposite the middle of the body which thus lies in the loop. The next process is the shedding of the last larval skin, which is rolled off and forms the unsightly débris that we often find near a chrysalis. The pupal skin is now exposed, and the ridges that outline the appendages of the butterfly are conspicuous. They are, however, but the outlines for which the necessary detail of muscle, nerve, and blood-vessel is yet wanting. On the surface all appears quiet and rigid ; a wag of the tail is the limit of response.

Within all is stir and change. The larval body is being dissolved and remoulded to fit the new existence. The creeping muscles of the caterpillar are broken down and rebuilt to form the flight muscles of the butterfly. The jaws are abandoned, and the lips transformed into an elaborate sucking-tube. The digestive tube is altered to assimilate fluid instead of solid food. The compound eyes undergo their intricate development, and the nervous system which is to control the new and complex organisation is itself undergoing rapid concentration. In dimness and stillness, without any perceptible controlling mechanism, the tissues of the caterpillar are reformed and the basis of the future responses is laid down. The specific characters of structure and of colouring are being added. When these changes are in process the use of certain ridges and spines becomes clearer. The delicacy of the internal organs is extreme, and any pressure would deform them ; hence one reason for the presence of projecting spines upon which the stress may fall, and so be diverted from the inner yielding skin.

When the metamorphosis is complete the pupal skin cracks, and the butterfly, still with intricately convolved appendages, steps out. Its surface is wet, but as the air fills its breathing tubes, the limbs and wings dry and strengthen. It clings tenaciously to its surrounding holdfasts, whilst its muscles gain tone, and the nervous system begins to control the new mechanism. Finally the response to the new order,

within and without itself, issues in a concerted movement, and the butterfly flies away.

The Diptera or Two-winged flies.—The most important groups of insects are those whose life-histories are more rapidly traversed, or exhibit more profound adaptations for the welfare of the species, than those we have so far reviewed. These are the Diptera or two-winged flies, and the Hymenoptera.

Flies are one of the scourges of the earth. They have no fear. To them the persons and dwellings of animals and men, and all that comes from them, afford nourishment and shelter. They pierce and suck with the finest and most elaborate of instruments. They transmit typhoid, malaria, cattle-disease, and sleeping sickness. They devastate prairies, and what they do not kill they spoil. Wherever man goes they dog his steps, and where he lives there the house-fly follows. Beelzebub was the appropriate symbol for such a scourge. Each winter of our climate promises to end the plague, and clears the air and earth of flies. But that avid life escapes all checks. In every mild break small gnats emerge, and some fly shakes a loose leg in mockery at the season's persecution, and with the approach of spring detachments of the vast battalions issue from cover. Even in the cold of northern Siberia, where spring and summer form but two months of the year, the mosquito then hangs as a veil over the rivers. In the fly's sight earth and its waters form a vast nursery; its covering of verdure a sustaining drink; its inhabitants a still more stimulating

FIG. 51.—The female House-fly (*Musca domestica*). The head of the male is seen in outline.
(*By permission of C. Gordon Hewitt, The University, Manchester.*)

nourishment, forcing into rapidly recurring broods the development of their young.

Our common flies are highly organised. Though the house-fly is the first animal we meet, it is the last we know. Concerning it, as of most familiar animals, Aristotle's apophthegm holds good, that what is first in nature is last in genesis. The fly, like all beings, is an old hand, yet historically it is a new-comer, and proclaims the fact in its structure, habits, and life-history. We may therefore lead up to it by some less specialised forms—namely, the mosquitoes.

Of this large family the gnats, mosquitoes proper, and the harlequin flies may be taken as examples. The first may be roughly distinguished by its habit of resting on its fore and middle legs, holding the last pair in a raised position; the second, by its yellow and black colouring; and the last by its habit of raising the fore-legs when at rest.

The Gnat.—The two sexes of the common gnat are easily distinguished. The male has bushy antennæ, the female has slender antennæ with inconspicuous hairs inserted at each joint. The males associate in large companies that dance over the country-side, whilst the female is more solitary and rests often in outhouses and near or in dwellings. Lastly, the blood-sucking habit is peculiar to the female.

In early summer the female lays her eggs in little boat-shaped floats, on the surface of water standing in butts or on marshy ground. The float is rather less than a quarter of an inch long, and contains

250 to 300 eggs. Each egg is cigar-shaped, with the narrow end turned upwards, floating with the tip projecting through the surface-film into the air. By this means the float is made self-righting, for if submerged it carries down between the pointed egg-tips a bubble of air and almost instantly rises again to the surface perfectly dry. The 'surface-film' is an expression of the elastic property of the surface particles of water. The tenseness of this film is readily seen in soap-bubbles, and the use of it by insects has led to many biological adaptations. In the present case the hold which the eggs gain on the film provides them with a constant supply of air.

The next day the larvæ hatch out. They differ from the early stages of the insects so far considered in having no limbs. Each larva is a minute, colourless, worm-like organism, consisting of a small head provided with biting mouth-parts, a swollen thorax of three segments, and a segmented abdomen, at the tip of which are some peculiar processes. The behaviour of the gnat-larva is characteristic. When at rest it hangs head downwards from the surface-film. From time to time it releases its hold and descends passively, then wriggles again to the surface. This swimming movement is performed by bending the body into double and reversed curves, and progresses tail foremost (fig. 52).

The larva gains a hold on the surface-film by means of a peculiar projection—the siphon—attached to its tail. This siphon is a tube opening by fine flaps

which may converge to a point and close, or may diverge and open. Connected with the siphon are breathing tubes or tracheæ that supply all parts of the body with air, and in particular a little group of tracheal gills placed near the siphon. Accordingly, when the larva rises to the surface it closes the valves and so pierces the surface-film. It now opens them, and they rest upon the elastic film-membrane without breaking it, just as muslin or gauze remains unwetted. The pull of the film on the five-lobed plate suspends the larva. To descend, it closes the valves, thus reducing the tension, and is drawn downwards by its own weight. The food of the larva consists of minute organisms which it sweeps into its mouth by the tireless action of its jaws.

FIG. 52.—The larva of the common gnat (*Culex pipiens*) in its characteristic attitude. It is attached to the surface-film of the water by its breathing siphon, and hangs head downwards. (*From Miall's 'Natural History of Aquatic Insects.' By permission of Messrs. Macmillan & Co.*)

After three or four moults, being a week old, the larva passes into the pupal state for two days, but, unlike the pupæ we have so far considered, that of the gnat is an active organism. It consists of a large

globular anterior mass (the head and thorax), and of a flexible abdomen. Unlike the larva, however, it now comes to rest at the surface-film with the globular head upwards and the tail downwards. This change in position is significant, and is effected by two hairy horns or minute trumpets that project from the back

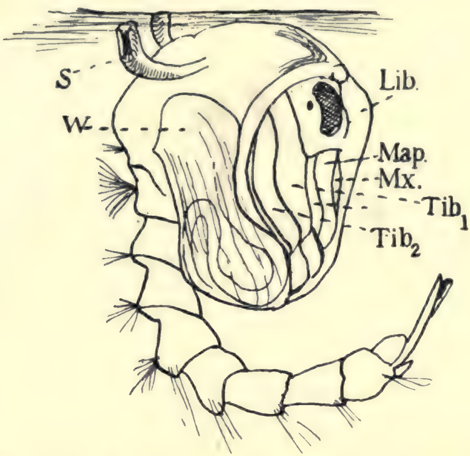

FIG. 53.—The pupa of the common gnat in its characteristic attitude. The respiratory trumpets (S) maintain a hold on the surface-film of the water. The wings (W), legs, antennæ, and mouth-parts can be seen. Of the mouth-parts *Lib* is the large upper lip, *Mx* and *Map* the lower lip. *Tib*$_1$ refers to the first leg; *Tib*$_2$, to the second legs, the third is seen under the wing.—(*After Hurst.*)

of the thorax. These are now the outlet and inlet of the tracheal system. The hairs lining them suspend the body by the tension of the surface-film, whilst a stroke or two of the tail, aided by the tail-fin, severs this hold and carries the pupa downwards,

ascent being a passive movement. The significance of this change in posture is seen when the fly emerges. The crack through which this occurs lies on the thorax, and if this were submerged the gnat would drown. Hence the advantage of carrying the arched thorax uppermost. The gnat at once gains the air, straightens and dries its lancets, antennæ, legs, and wings, fills its air-tubes, and flies away.

The Mosquito.—The mosquito (Anopheles) passes through a life-history similar in all essentials to that of the common gnat. Its larva may, however, be recognised by certain peculiarities, of which its habit of lying horizontally instead of vertically is one of the most obvious. The mature insect is found in most English counties, but is most abundant along the chief river-valleys and over the Fen district. This distribution agrees closely with the occurrence of ague in former times, and the spread of this fever is now generally recognised as the work of the female mosquito. Allied forms are even more noxious in this respect, and it is certain that malaria is caused by the infection of germs of the disease introduced into the blood during the act of sucking.

The Harlequin Fly.—Of the vast number and variety of midges and of gnat-like insects that succeed one another with the course of the seasons, but few are adequately known. In a casual view they are lumped together by their general superficial likeness, and their assumed uniform taste for blood. The professional naturalist splits them into a vast array

of species, on the assumption that they all breed true, and it may be that he is right. But until we know the life-histories of the spring and autumn broods of the same gnat races, there is a possibility that seasonal forms of the same species may occur, and that these may have been regarded as of specific instead of varietal value.

The harlequin fly (*Chironomus*) is one of the commonest insects that are mistaken for true gnats. It possesses a form similar to that of Culex, and is found in like places under similar conditions, but it can be recognised by the entire absence of a proboscis. It can neither pierce nor suck, and in all probability does not feed.

The eggs of *Chironomus* are laid in gelatinous strings about an inch long, moored to the banks of streams and the margins of troughs. The jelly is traversed by twisted fibres about which the hundreds of eggs are arranged spirally. These egg-ropes are an interesting adaptation to aquatic conditions. The strings moor them elastically. The mucilage protects the eggs from predaceous and insidious foes. It raises them to the influence of light, heat, and air, and it enables the eggs to be spaced out without over-crowding. Incidentally this transparent envelope permits direct observation of the development, as Professor Miall's books have so fully shown.

In a few days—three to six, according to the higher or lower temperature—the larvæ hatch out of these eggs. They are colourless vermiform organisms,

and move actively by reversed figure-of-eight twists of the whole body. The head is small and differs from that of a Culex-larva in having rasping teeth instead of a sifting arrangement. The tail-end is marked by a pair of hooked feet, and between these lies a minute coronal of four gill-plumes. The larva has no opening to its tracheal system, and does not attach itself to the surface-film. On the contrary, it buries itself head downwards in a burrow or case formed by particles of mud glued with saliva, and if the water contains sufficient air the larva respires by gentle undulations of the tail, causing a current that flows over the skin and tail-filaments. It only leaves the burrow at night. If the larvæ live on a hard bottom they form a portable case of débris. Larvæ which inhabit stagnant or sewage-water acquire a red colour (hence their name, blood-worms), whereas those of aerated water are greenish. This difference of tint is due to the presence of red blood in the one case, and of colourless blood in the other. The red colouring matter is identical with hæmoglobin, and its presence confers increased respiratory efficiency on the blood, in virtue of which the harlequin fly can pursue its larval life in foul water and at considerable depths. This is not the only adaptation enabling these larvæ to utilise very small quantities of oxygen. The surface-forms which can utilise the dissolved oxygen have no tubules at the hinder end of the body, whilst those which inhabit deeper water have two pairs of vascular tubes on the last segment, and these in all

probability help to increase the respiratory surface of the skin.

The length of the larval life of *Chironomus* varies with the seasons. Spring larvæ grow rapidly, and in a few weeks pass into the pupal stage, whereas the autumn broods grow more slowly and do not pupate till the winter is over. Before this stage is reached the rudiments of the future wings and legs can be detected as coiled tubules lying in the thoracic segments. When the last larval skin has been cast, these and other organs of the fly can be seen more clearly. They form a large mass occupying the anterior end of the pupa, from the thorax of which a pair of tufted filaments projects freely. This portion of the body sways above the mud, below which the rest is concealed. The tail-tubules have disappeared, and a broad fin has formed which is used for movement through the water. In two or three days the thoracic filaments have extracted sufficient oxygen from the surrounding water to render the pupa buoyant. The oxygen is stored in the tracheal system, which rapidly becomes fully developed. The pupa now floats at the surface, and on the last day or so inhales air directly from the atmosphere through the spiracles or breathing holes. At length the pupal skin splits along the thorax, the fly creeps out, dries its wings, and in less than a minute flies away.

The life-history of *Corethra*, a close ally of *Chironomus*, is almost equally easy to follow. In still pools the early stages of this gnat-like insect are developed

from eggs arranged in spiral lines on a flat gelatinous sheet. The larva is of a glassy transparency, and lies still and horizontal below the surface of the water, only changing its position by an instantaneous jerk, and again floating motionless. The momentary gleam as it turns reveal its presence, and has gained for it the name phantom-larva. Upon closer examination these organisms are found to resemble fig. 52. The head bears antennæ, two complex eyes, and a peculiarly constructed mouth enclosed between the two lips and the jaws. At the back of the throat is a fringe of stout bristles arranged like the bristles of a lobster-pot, so as to strain the food, the result being that no opaque substances collect in the body and break the transparency of the larvæ. The food itself consists, according to some authorities, of small creatures which are caught by the antennæ and chewed up in the mouth ; according to others, *Corethra*-larvæ feed on the fine microscopic life of ponds. The horizontal attitude of the larva in the water is aided by two pairs of vesicles filled with air or gas. These air-sacs are special expansions of the reduced tracheal system which runs as a closed pair of tubes down the body, and is filled by diffusion.

The further history of *Corethra* resembles that of the gnat. The organs of the fly appear as convolved protuberances. A pair of air-trumpets sprout from the thorax and lead into a new system of tracheal vessels. The old tubes break down, and the contained gas collects into a bubble beneath the thorax. The

pupa appears and floats vertically at the surface of the water. It emits the fly directly to the surrounding air.

Owl-Midges.—Allied to the gnat-family is that to which the midges belong. Of these numerous and varied forms, the minute *Ceratopogon*, or owl-midges, are amongst the most familiar insects. They form the clouds of minute hairy-winged insects that emerge at sunset from cover, and sting with the virulence of a mosquito. Allied to these owl-midges are other species with smooth wings. The larvæ of these insects have a simple worm-like shape. Those of the hairy-winged midges live on the sap of wounded trees, and under the damp bark of dead timber, creeping, and even swimming about with great activity. The larvæ of the smooth-winged midges are commonly met with among the confervæ at the surface of ponds, and are also active swimmers. In this stage the midges pass the autumn, winter, and early spring. About May the pupal stage is assumed, which is characterised in the midges, as in certain other insects, by its retention of the shrivelled larval skin attached to its tail. Towards the end of this month, or a little later, the winged form appears, only too abundantly in enclosed gardens and the neighbourhood of water.

The Black-fly (*Simulium*).—The varied adaptations of dipterous larvæ to life in running and stagnant water are of considerable interest, and from the accessible, though still imperfectly known life-histories, we may quote two that illustrate these modifications.

The black-fly (*Simulium*) illustrates the first; the hovering fly (*Eristalis*) the second.

Simulium is a minute insect about one-seventh of an inch in length, and appears to be a relative of *Ceratopogon* if not closely allied to it. It is found in marshy places, flying about in great swarms in a slow and heavy manner, the fore-feet being kept in continual movement, and evidently employed as feelers. Though perfectly innocuous in this country, *Simulium* is one of the greatest scourges to which man or beast is exposed in Lapland, Hungary, the United States, and Australia. Horses, cattle, and buffalo are especially affected by this midge. A characteristic difference separates the sexes. In the male the head is much enlarged in consequence of the much greater development of the eyes, the upper facets of which are larger than the lower ones. The eyes of the female remain small and undifferentiated into dimorphic facets. The males swarm high in the air, whilst the females remain at lower levels. Both sexes occur in the late spring, and again in August.

Simulium lays its eggs in gelatinous masses on water plants that border rapid streams. The larvæ occur in clusters on leaves and stones, and are of such curious form and habit as not readily to be taken for insects. In appearance they resemble minute black leeches. The cylindrical body is fixed by a terminal sucker, in order to resist the current, and is provided at its free or head-end with a second sucker and a pair of revolving fans. When alarmed, the two suckers

are employed exactly like those of a leech, and in a few moments the larva creeps back to its first hold-fast, even if it has to work against the stream. How this is done can be understood by placing a white disc under the leaves. Against this background a web of dirty threads can be seen, and, as the larvæ drop, they spin a fresh line; along this they climb with their suckers. It is on these lines that their safety largely depends, and with their huge spit-glands they are constantly extending them as they move to fresh quarters.

These glands are also used for another purpose. Before pupation the black-fly larva makes a conical nest against a weed-stalk, and in this nest the pupal stage is passed. The larva, head downstream, constructs its chrysalis case of the hardened secretion of its glands, and then proceeds to undergo its transformation. At first the nest is closed, and only after the last larval skin is cast does the broad projecting end open, and then out there come the pupal head and the thorax, with two sets of breathing filaments, like those of the pupa of the harlequin fly. The pupa, fixed within the nest by hooks along its abdomen, is swayed with every movement of the weed. In moorland streams the vegetation is often thickly covered with these strange inanimate-looking tufted excrescences, within which all the organs for aerial life are developing or completed.

How, from this submerged fixed pupa, the fly could safely emerge was long a problem. Unlike

those of the other gnats and midges, this black-fly pupa does not float and cannot leave its nest, yet the flies pass the gauntlet of the stream. They emerge safely in thousands, and may be seen clinging to weeds on the borders of the stream. The method of hatching is singular. The pupa not only stores air in its breathing tubes by diffusion, but actually distends its skin therewith, and so separates it from that of the fly. Ultimately the pupal envelope bursts and the fly emerges, still with intricately contorted appendages, and surrounded by a bubble that clings to its hairy covering. In a moment it rises glistening to the surface, where the bubble bursts. Its legs spread out with almost explosive suddenness; with these it easily runs on the surface-film, climbs up the nearest support, and then expands and dries its wings.

The Drone-fly (*Eristalis*).—In great contrast with these remarkable adaptations of midge-larvæ and pupæ to life in flowing water, are those shown by the drone-flies, and some daddy-longlegs in their earlier stage of development. The larvæ of these flies are elongate, whitish, worm-like maggots, with a long rat-like tail. Their breathing tubes are well developed, and open to the surface at the tip of the tail. By the aid of a telescopic arrangement this tail can be protruded to a length of some inches, so that while the larva is buried deep in mud, its breathing tubes can reach up to the surface of the water, break the film by the point or hooks of the tail and acquire a supply of fresh air. This arrangement is most highly

developed in the drone-fly (*Eristalis*) larva, a scavenging creature that does immensely valuable service in rendering stagnant water and decaying substances innocuous. This larva, the ' rat-tailed maggot,' though only two-thirds of an inch in body-length, can extend its tail from half-an-inch to four inches in length, drawing it out to a mere colourless thread, and at the least alarm shutting it up in a flash. The mode of feeding no less than the breathing of this animal shows a most complex form of adaptation. The organic débris on which it lives is highly innutritious, and a special collecting apparatus has arisen to enable the bee-fly larva to make good the lack of quality in its nutriment. This apparatus is a strainer opening inwards, placed between the mouth and the gullet, and dividing the gullet into upper and lower chambers. The larva roots about with its flexible muzzle, and, having loosened a quantity of débris, gulps down a mouthful. This passes easily through the strainer and is sucked into the upper chamber. Then the water is forced back, filtered through the fringes, and discharged through the mouth, whilst the food is left stranded on the strainer. The process is repeated again and again. When a sufficient quantity has accumulated it is converted into a bolus and swallowed. The action of the fringes is curiously like that of the baleen-plates of a whale.

When this rat-tailed larva is about to pupate, it leaves the water, enters damp earth, and conceals itself beneath a cocoon made of the larval skin, dis-

coloured and hardened. Within this, its organs undergo profound changes, and new ones appear. Two pairs of horns project at the head-end and form the respiratory openings of the pupa. The tail severs its connection with the body. The wings, legs, and elaborate proboscis appear, and in favourable seasons the fly is ready to emerge in eight to ten days from the commencement of pupation.

If we now turn to the terrestrial larvæ of the two-winged flies we find that they affect such a great variety of habitat and food, and undergo their development at such varying rates, that a whole volume would not exhaust the subject.

There is every transition, from the terrestrial to the aquatic habit, from the free-living to the purely parasitic mode of life. The possibilities of nature seem to have been almost exhausted by these insects in their efforts to fill every available niche that shall afford nourishment for the growing period, retirement for the development of the pupa, and exercise for the instincts of the imago. In particular the value of heat has been utilised to the utmost as a means of assisting growth and development, and so producing swarm after swarm in a single summer.

The many tribes of blood-suckers use this stimulating nourishment to force their progeny. The parasitic larvæ hasten their development in the warm hides of flocks. When these hot-houses fail, cold-blooded animals, vegetable juices, fungi, pools in hollow trees, serve as substitutes. Only one advance seems possible

in perfecting the adaptations of Diptera ; that is the step taken by the next group. Were division of labour adopted by flies as by bees, it is doubtful whether domesticated animals would survive or vegetation flourish. But in all the unequalled variety of dipterous habit, there is no indication of the adoption of communal life. The common household flies and the horse-flies are individualists of the highest order. In no other animals are the two diverse ends of life so strongly emphasised. In none are they embodied in more glaring contrasts than in the inactive maggot and the brilliant hovering fly, the one a nutritive centre, the other with only the need of drink to ally it to earth. In no other life-history is the transition so rapid and abrupt. The chief larval tissues are resolved to a cream, and are rebuilt in a week to form a far more complex and active being.

There is no comparable adaptability elsewhere to ensure as these flies do, the forcing influence of heat and stimulating food, or to utilise borrowed animal heat and nourishment in order to produce, not eggs, nor even young larvæ, but a full-grown larva, or even pupa, which needs but a few hours to complete the issue of the fly. And the genius of the Diptera lies in this, that without forsaking their hold on the old inexhaustible vegetarian diet, they have been drawn by the attraction of smell to the new kingdoms of mammals and birds, with all that goes in their train.

The Hymenoptera.—The care of the young is most efficiently performed by the *Hymenoptera.*

Although many other orders of insects lay their eggs on food suitable for the young, it is only among ants, bees, and wasps that nests are constructed and stored with specially prepared food by mothers that never see their young, or by workers that have no children. In this, the highest group of insects, individualism and collectivism are worked out in the most bewildering variety of detail. In no other group of animals is the community and communal action more fully realised than by bees and ants. The very existence of castes,.queens, workers, and drones is controlled by the future of the race. Their numbers and activity are decided by, and devoted to, the welfare of the community. The construction of the nest and cells or comb, the laying of eggs, and storage of special food in the egg-cell, and in reservoirs against bad weather, the heating of the nest, the provision of suitable moisture and the succession of swarms—all the characteristic activities of these *Hymenoptera* have no relation to the workers' individual needs but are directed to the colonial interest. So dependent on society do the members become that, in the case of ants, no isolated worker can live more than a short time, though normally a long-lived creature, and there is not a single species of ant which is solitary. So altruistic are some ants, so specialised for the furtherance of interests not their own, that they may lose the power of feeding and cleaning themselves, and depend for these offices on the service of slaves, whilst their own activity is devoted to the defence of the colony.

The more these social creatures are studied the more clearly does it appear that their behaviour is regulated far more by future contingencies than by present needs, and that they present in the organisation of their communal life and in their adaptation of plants and animals to their needs and those of their offspring, a civilisation which though many ways similar to the early stages of human civilisation, shows a still more striking resemblance thereto in the plasticity whereby advantageous seasonal or local peculiarities are made use of and destructive agencies avoided or overcome. If we meet with instances of stupidity and inflexibility, these exceptions do but emphasise a frequent parallel in human frailty. There is an American saying that the ant is King of Brazil, and only want of sublimity of form prevents us from confessing the ant as king of animals, for in it intelligence rules as well as instinct, and has controlled a civilisation of caste that is devoted beyond human parallel to the welfare of the state.

The common ants, bees, and wasps are, however, only a fraction of the order *Hymenoptera*. In addition to the more familiar social members of these groups there are large numbers of solitary bees and wasps whose care for their young is no less wonderful. Just as we study the smaller races of mankind, or the insignificant early traces of dominant nations, in order to understand the complex forms of western or eastern civilisation, so the dominant familiar insects only become tolerably intelligible when the less highly

organised economy of their simpler allies is made known.

Amongst these less impressive forms are the saw-flies, gall-flies, and ichneumon-flies. The saw-flies are easily distinguished by the absence of a 'waist,' and the possession, in the case of the abundant female, of a sting-like organ consisting of two remarkable saws and their supports. By the aid of this apparatus the mother fly is able to cut passages into the leaves, stems, or trunks of plants before depositing her eggs therein. The gall-flies are minute, pitchy-black, thin-waisted insects which may be identified by their straight antennæ. The ichneumons are thin-waisted and often brilliantly coloured insects, the mothers bearing a usually long sting-like weapon for depositing their eggs in or upon the bodies of caterpillars.

Saw-flies.—The saw-flies of the rose, gooseberry, currant, and turnip do an immense amount of mischief in this country, and abroad, where the conditions are more favourable, their ravages are correspondingly severer. The gooseberry fly lays its greenish eggs along the mid-rib of the leaves, and from them there issue in a week minute white larvæ with twenty legs and sucker-like feet. At the first moult they assume a green colour spotted with black, and in many ways resemble true caterpillars, as, for instance, in colouring and attitude and in the possession of prolegs. After feeding for a month they become yellow in tint, creep down to earth and pupate, or may hibernate and pupate in the following spring.

Gall-flies.—In contrast to the free-living larvæ of saw-flies, the gall-fly's young spend their whole life within excrescences on oaks, willows, and roses. How these galls are made has long been a moot problem. That some great advantage is gained from these local inflammations of plant-tissues is clear, both from the great variety of gall-forming creatures and the close association in one and the same gall of diverse insects, some of which have entered it after the inflammation had begun ; and it seems probable that the attraction is due to a very concentrated form of easily digestible, nutritious, and inflamed tissue. Each plant responds in a characteristic fashion. The bedeguar or rose gall, and witches-brooms on birches, are modified shoots ; the oak-apple is an aborted leaf ; the willow-spot is merely an inflamed part of a leaf ; and it was long thought that the plant parasite, be it fly, scale, or mite, inserted an irritant fluid with its egg into the bud or leaf to which each plant responded by these several wonderfully specific outgrowths, thereby concentrating tender rich juicy tissue into a compact space about the egg, and so furnishing a supply of stimulating food to the larva. In the case of the gall-flies, however, irritation does not usually follow the insertion of the egg until the larva hatches out, and there sometimes follows an interval of ten months before the gall begins to grow. From such observations it has been concluded that the gall is due, not to an irritant fluid injected by the parent, but to something secreted by the larva ; and the cases

where gall-formation has undoubtedly begun before the time of hatching are probably to be explained as due to the influence of the larva making itself felt through the egg-membrane.

The larva of the gall-fly having no cause to wander in search of food, and being shut off from most of the changeable conditions of free life, possesses a simpler structure than that of the saw-fly. Its colour, like that of most hidden animals, is white. No limbs are present and the bent body merely turns about from side to side, as it slowly drains the wall of sappy or pulpy material that has grown around it. This supply lasts it for several months, after which it pupates and issues as a fly in the next spring. In many cases it has been found that the gall formed by it in turn is different from that which produced it, and whilst the first generation is entirely composed of females, the galls, stimulated by their larvæ, produce in the next season both sexes; and this generation is so different in appearance that it was for some time considered to be a totally distinct form. To what cause we can attribute this difference in the two successive generations is not yet thoroughly clear, but the fact that the two galls are unlike points to a slight difference in the food. The influence of change of diet upon young insects is known to be a far-reaching one, and as any check in the flow of sap is sufficient to convert an aphis of one kind into an aphis of a different category, and as a stimulating food will produce a queen bee from a worker egg, so it may be in this case, that a

difference in the position of the two galls or a variation in the quality of the sap at different seasons will lead to an explanation of the fact that the gall-fly has two differing generations.

The act of piercing the skin of plants, and of then laying eggs in the puncture so produced, is performed independently in many groups of insects by the same complex surgical instrument. It is, however, only in the higher *Hymenoptera* that the organ becomes, by the addition of a poison-bag, a sting. The value of this office is best seen in the solitary wasps.

Solitary Wasps.—The social wasps are so familiar that the term wasp has become almost synonymous with the species that form communities ; and to many the less impressive solitary wasps are quite unknown. Yet they are common enough in this country, and their habits excited the admiration of observers before the beginning of our era. Few of those who have lived in the country will have failed to notice the absorption and persistence with which a 'fly' will have established its quarters in a keyhole, dressing-table, or some other part of the furniture which may be reached from an open window or door. The movement and the life of the house makes no difference to the constant visits paid by this insect when its mind is once made up to fix its abode there. With unerring certainty it flies in by a straight course, executes its business, and flies away by an undeviating line. Should the spot be examined the insect will return and hover impatiently until its task can be resumed. The work

itself is a mass of clay worked, sometimes with stones, into a vase-like or irregular shape. When broken open the nest is found to contain a surprise, for instead of the white wasps' comb, or the grubs that we should perhaps expect to see, a mass of caterpillars is revealed. The caterpillars are all of one kind, and usually to all appearance dead. But if dead they have none of the shrivelled appearance that in a few hours overtakes a caterpillar killed by ordinary methods of starvation. These larvæ are still pliable and fresh in colour. They have no trace of the rank smell that issues from a naturally dead larva, and, if we keep them, they will long remain as fresh and healthy-looking as in life. But not one will come to life again. In a few days the wasp disappears, and may not return. It is clear that the extraordinary store of preserved caterpillars is not touched by the wasp. If the nest is not hopelessly destroyed by examination, it will in the course of a month produce one or more wasps of a like kind; but at the expense of the caterpillars. Either, therefore, the caterpillars become wasps or are in some indirect way transformed into wasp-bodies. The Chinese, from the time of Confucius at least, have noticed this strange transformation, and suppose that the wasp addresses to the caterpillar a message or spell 'to mimic me.' This the resigned caterpillar to all appearance does, and to this day the word 'Jiga,' or 'mimic me,' is the name by which the wasp is known in China.

The disappearance of the caterpillars is rendered

less mysterious if we open the nest at an earlier period, for then one or more white grubs will be found devouring the fresh food by which they are surrounded. The supply is, however, usually sufficient to enable the young to attain their full growth, and to pupate successfully. Careful examination of the earliest stage will reveal one or more eggs prone or pendent, which are laid by the wasp among the store of moribund caterpillars in the still earlier formed clay nest.

There is no doubt that the wasp makes the clay with its saliva, builds the nest, stores it with a particular insect, and then, after laying an egg or two, leaves the warmth of the situation to complete the development of its young. The entire work falls upon the female.

Sand Wasps.—These solitary wasps are of diverse kinds, and many dig burrows in the ground, construct cells of pottery, or tunnel into wood. In all cases it is the female wasp exclusively that does the work. The males usually live for a short time, and take no part in the construction of the nest or the care of the young. *Ammophila* of sandy districts is well known (Peckham, Fabre, p. 300).

For digging its burrow this wasp uses mainly the same instrument that others employ to collect earth for pottery work—namely, its strong jaws, aided by the first pair of legs. Having selected a spot on suitable ground, and on a hot day, the red-banded black *Ammophila* picks away the earth until she is partly

hidden ; she then carries it away, backing out of the hole with a pellet in her mouth, flying a short distance and 'flirting' the load away from her, repeating the journey until the ground is clear for further excavation.

The burrow is now deepened, and a storage chamber of much larger diameter is formed. When this is finally accomplished and the soil and stones removed, the wasp proceeds to cover up all traces that might lead to the detection of its burrow. She selects a stone or large lump of earth, and tries the effect of it as a stopper. Sometimes, as if satisfied, she proceeds to kick loose soil over the top to disguise all traces of her activity, more frequently the first, and many succeeding stoppers are rejected and more excavation must be done before the critical worker is satisfied, and finally, perhaps, a big lump is firmly wedged in with smaller stones and earth.

The next process after the construction of the nest is its storage with suitable food. For this purpose each wasp has its special and invariable choice. Though ripe fruit or nectar form their own food, that of the larva must be of animal nature and perfectly fresh. The wasp therefore now devotes herself to a hunt in which her own choice takes no part. It is the tradition of some to take flies, of others to select beetles, grasshoppers, spiders, caterpillars, or bugs. Moreover the selection when so narrowed is not indiscriminate, and usually one, or at most a few, of the selected class are captured for this purpose. The work, therefore, is rendered most arduous. *Ammo-*

phila quarters the ground and thick forests of herbage for caterpillars. Having found one she attacks at once, and tries to bite and to sting it. The caterpillar, however, flings itself about, strives to gain cover and repulse its foe, not infrequently, it would seem, with success. But on occasion the wasp succeeds in gripping the larva, and then standing high on her legs, and disregarding the struggles of her victim, she curves her abdomen under it and plunges her sting. The caterpillar instantly collapses. For some moments the wasp remains still. Then withdrawing her sting she plunges it into two more intersegmental grooves, each time nearer to the head, then she circles above it, and again descends and repeats the assault nearer the tail of the larva, stabbing it four times more. The attack over she pauses, cocks up her tail, washes and rubs her face thoroughly and completes her toilet. Her next task is to drag the heavy prey to the nest. Holding it with her teeth and forelegs she passes rigidly over rough ground, standing corn, or garden plot, where there is nothing to suggest the right direction. Yet over all this, for sixty feet or more, she travels without hesitation, pauses, lays her burden down, and presently removes a stone or two and reveals the nest ; then hurriedly returning to the caterpillar she picks it up and takes it to the burrow. There she drops it and, backing in, catches it with her mandibles and disappears. When the caterpillar is secured a single egg is attached to its skin, and then the *Ammophila* goes out again hunting

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for another. On the average she finds one a day, and when the second is found it is sometimes only slightly stung and then softened and rendered pliable by forcible pinching. This done the wasp carries it off and deposits it as before, guided by the same inscrutable, intimate sense of locality back to its hidden nest.

The store is now complete, and the *Ammophila* proceeds to fill up the burrow. In this finishing process, as in the initial one, she shows remarkable individuality of behaviour. Some wasps carefully fill the hollow, smoothing the surface, sweeping every particle away, and trying the effect of a leaf, or twig, as a finishing touch. Others merely scratch a little loose earth into a perfunctory burrow. Others again give an extra finish by using a selected stone in their mandibles to beat the surface hard and smooth. The site is then deserted, another is chosen and the work of learning a new locality thoroughly, of making and stocking a new burrow are gone through afresh.

The incessant ardour which these attractive solitary wasps exhibit in nest building and storing is a wonderful feature. As a rule they work without ceasing from dawn to dark, retire to roost in long grass or under clover about seven or eight o'clock, and after shifting from one posture to another, sleep soundly until about five, though some do not get up till eight.

Their strenuous encounter with poisonous spiders, or powerful crickets and grasshoppers ; their ways of carrying or concealing the prey until the burrow is

enlarged to allow it to pass in, the construction of mud cells by some, of earthy hollows by others, are fixed habits of the several kinds of wasps.

Nevertheless, a certain improvement in their habits, due to experience, is undoubtedly exhibited by many. The adoption of chimneys or eaves of buildings is an improvement on the older method of using hollow trees or shelving rocks. Again, the spider-hunter has found that to hang up its prey in a fork while finishing the burrow, instead of leaving it on the ground, is a safeguard against ants. She has also found that by cutting off the spider's legs more booty may be stored in a given space, and though exceedingly conservative in going through the operation by putting it down at the burrow's edge, investigating the nest and then pulling the spider down into it, yet she is not such a slave of custom as to be unable to adapt her action to changed circumstances, and if the spider is repeatedly removed while the wasp is in her burrow she will ultimately abandon the preliminary survey and drag her prey straight down, going backwards.

Social Wasps.—The chief advance made by these more familiar wasps over the solitary species lies in the evolution of the worker. The care of the young in the solitary wasps is entirely the work of the mother, who is both queen and worker. For the first few weeks of spring the same is true of colonial species, but, later on, the construction, protection, and provisioning of the nest is taken over by the workers, whilst the queen,

relieved of these duties, confines her labours to stocking the cells with eggs.

With the first warm days of the year, the queen wasps issue from their several hibernating places and quarter the ground in search of suitable sites in which to found the colonies. A hollow tree, a shelving bank, or an earthen crevice provide the necessary protection, and having selected the site the queen proceeds to build her nest. The substance employed for this purpose consists of wood-fibre, chewed to a pulp and thoroughly mixed with saliva till it forms a paper-like substance. With this wood-pulp the queen constructs the foundation, central support, and covering dome. To the underside of the dome she next affixes a few hexagonal cells. In each of these she places an egg, adds honey, and closes the aperture. In this way the first comb or tier of cells is prepared. The development of the brood is rapid, and issues in a small swarm of workers, which remain in the nest, as they are incapable of founding a new colony. They enlarge the existing cells and add comb after comb of new ones, stocking each cell, when the queen has laid in it, with honey and pollen. They extend and strengthen the dome and narrow its entrance, so as to form a small circular opening, such as is shown in fig. 54. Throughout the summer, brood after brood of workers issues from these combs, so that in September they form a plague in the neighbourhood of the colony. Finally a few queens and drones are born, probably by reason of a highly nutritious nitrogenous diet.

The appearance of these royal members marks the decline of the colony. The workers and the old queen perish, the nest is forsaken, and is soon demolished by shrews and other animals, and of the rest only one or two queens persist to carry on the laborious work after a long sleep in winter quarters.

Solitary Bees.—The care of the young is a no less fascinating study in the solitary bees. In early spring

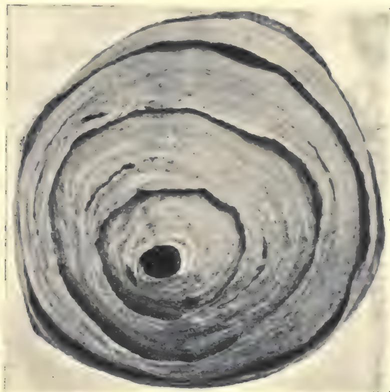

FIG. 54.—Nest of Common Wasp.
(*From a specimen in the Manchester Museum.*)

one may see these little burrowers preparing their nests on sandy banks, selecting bramble stalks and other hollow stems, or reconnoitring shells and crumbling walls. As the solitary wasps are to the social ones as cave-dwellers to fortunate citizens, so are these bees to the hive bees. They work incessantly during the summer, and then, with few exceptions, both dwellings and dwellers perish. The males are often

very unlike the females, and there are no workers to divide the labour of cell-making and honey gathering from the work of the queen bee in founding of the race. Unlike the solitary wasps, none of them use animal food for the nourishment of their young. Honey and pollen have to be stored in increasing quantity as the larvæ become more voracious and insistent in their demands.

FIG. 55.—The Leaf-cutter Bee (*Megachile*) that drills its burrows in coastal pathways. The upper figure with expanded tufted legs is the male.—(*From a specimen in the Manchester Museum.*)

Of these solitary bees the dark-coloured garden *Prosopis* is perhaps the most interesting. Not that she is impressive in appearance, or especially attractive in behaviour. She has hardly a hair to hide her nakedness. Her black and white body bears no baskets to carry pollen. She cannot produce wax nor dig dark earth, nor bore wood ; her jaws and limbs are too feeble, and her tongue too short. Poverty-

stricken and solitary she selects a hollow stem, a mortar or an earthen crevice, and there lines the hollow with a few irregular cells, enveloped in silk spun from her mouth. These she stores with a little wet honey and with pollen, which she scrapes into her mouth with her feet and then carries in her stomach, and soon after perishes.

The reason why *Prosopis* is interesting lies in that significance which gives to all antiquities their real value. Dominance, vigour, high and complex organisation appeal to us at once, for of such qualities our own civilisations partake. But it is not in these manifestations that we gain insight into the history of the race. We may realise the qualities that have determined its distinguishing character, and the complex factors that have modelled its political life, but the source from which it sprung is hidden from us by a thousand years of interwoven crossings of clan and clan, the battles of kites and crows, the dominance of one line of policy after another, the gradual disentanglement of the stablest form of government to suit, now one period, now another. To understand fully the genius of the people we have to go back to its origins, to the rude forefathers with their primitive strength, grace, or enterprise, and so ultimately to the cave-dwellers, the early hunters and artists. The neglected troglodytes, unimpressive, too often extinct and unavailable, are those races which would help us most. But these we have exterminated or decimated, and such truly original knowledge as they alone possess is too often lost to us

for ever. *Prosopis* is one of these antique races. Her poverty, isolation, and simplicity are no marks

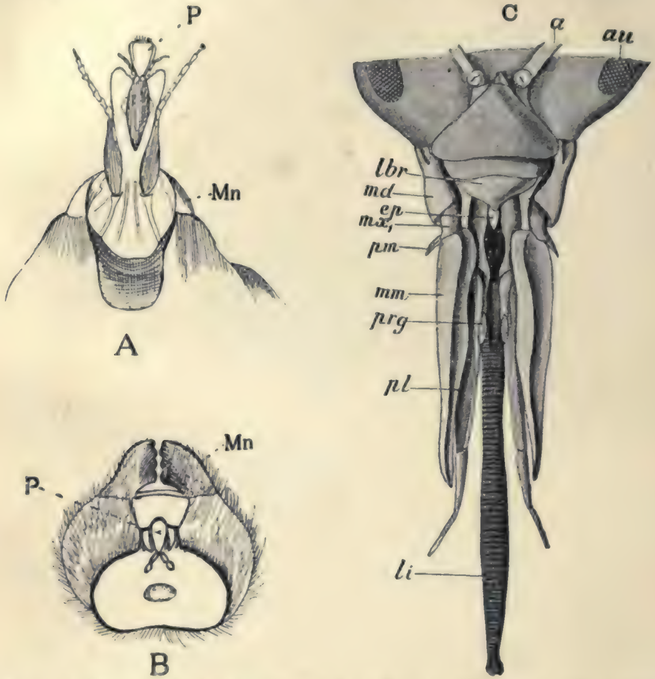

FIG. 56.—Evolution of the tongues of bees: A, trowel-like short tongue (*p*) of *Prosopis*, with the mandibles (Mn) at its base; B, jaws of Rose-cutter Bee (the tongue being turned back); C, elongate honey-sucking tongue of Humble or Hive Bee. The mandibles (*md*) are short, but the tongue and its adjacent parts (*li*, *pl*) are greatly produced.—(A, B *from H. Müller*, C *from Lang.*)

a, antennae; *au*, eyes; *ep*, dorsal groove (epipharynx); *lbr*, upper lip; mx_1, *mm*, maxillae.

of distress or degradation. Her short tongue and slender legs are signs of an antique habit that sufficed the needs of early bee-life, and in the eyes of the

naturalist give her a more profound significance than all the high organisation of the honey-bee. The garden in which she lives is in large measure her own work, for its flowers and fruits are responses to the stimuli that countless generations of her descendants have

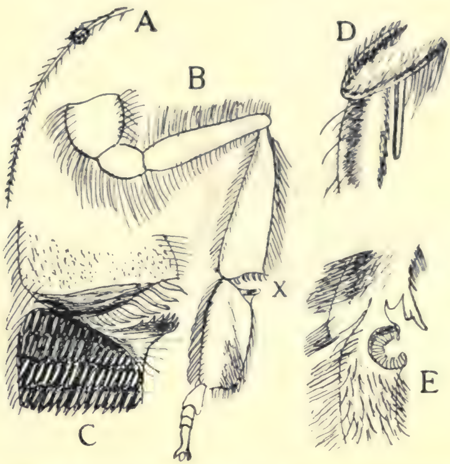

FIG. 57.—Adaptive structures of the Hive Bee for comparison with fig. 58. A, Feathered hair for collecting pollen. B, Hind-leg of worker. C, Inner surface of the part marked x in B to show the stiff hairs for gathering pollen and the wax-pincers. D, Spur on the middle leg for removing pollen. E, Comb on the fore-leg for cleaning hairs. (*After Folsom. 'Entomology.' London: Messrs. Rebman, Ltd.*)

successively applied to corolla, stamens, and stigma, as their tongue grew longer, their legs more capacious, their wax plates more generous. The history of flowers would almost be a blank, but for the *Prosopis* and her vast following; a hundred thousand varieties would disappear if the bees did not visit them; and

if we reflect how much human civilisation in its critical pastoral and tribal stages has depended on agriculture we realise how greatly we are indebted to these honey-suckers and pollen gatherers.

Not all the solitary bees are so destitute as *Prosopis.* The majority are well clad, hairy-legged

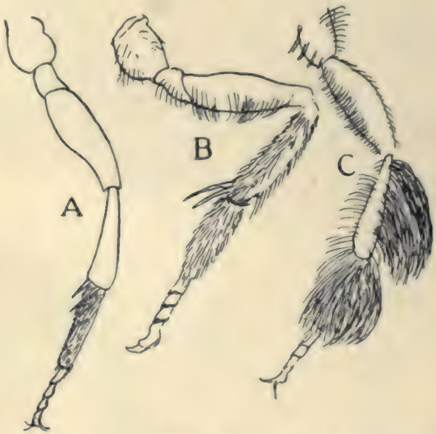

FIG. 58.—Hind-legs of three Solitary Bees : A, the smooth leg of *Prosopis* with no pollen-gathering apparatus ; B, leg of *Halictus* with short hairs ; C, leg of *Dasypoda* with great tufts of pollen-bearing hairs.—(*After Müller.*) Figures of these bees are given by Sharp (see p. 300).

burrowers. Some carry pollen on their furry breasts, others on their thighs. Some dig in the ground, shovelling with their legs, and excavating first a gallery and then brood chambers which are stocked with balls of honeyed pollen. Others construct a tunnel in a bramble stalk, and beginning at the lower end store ball after ball and egg after egg, in single file, until

the tube is full. The leaf-cutting bees line their earthen nests with a layer of leaf-discs and construct thimble-shaped leafy cells in which to store their pollen and lay their eggs. The carder-bees drape some ready chink with wool or cotton which they gather from plants near by. In these various ways they lay and feed their young, and defend them against mould—that most insidious and deadly of their enemies.

Mouldiness is, however, not the only foe the bees

FIG. 59.—Burrow of the Leaf-cutter Bee (*Megachile centuncularis*). (*From a specimen in the Manchester Museum.*)

have to fear. Another and more widespread enemy is ever ready to annex their ingatherings. The tendency to take what others have gathered and to divert the store for their own ends exists in all capable organisms, and amongst bees there is a whole tribe of cuckoos who plant their eggs in others' nests. Even those steady workers, the mason-bees, will, if interrupted, carry their provisions to a neighbouring, completed cell, and there strive to gain a footing, and many other solitary bees, if delayed or unable to finish their tale of cells, will tear what they have done

to pieces, devour the eggs, scatter the contents, and start provisioning and stocking afresh.

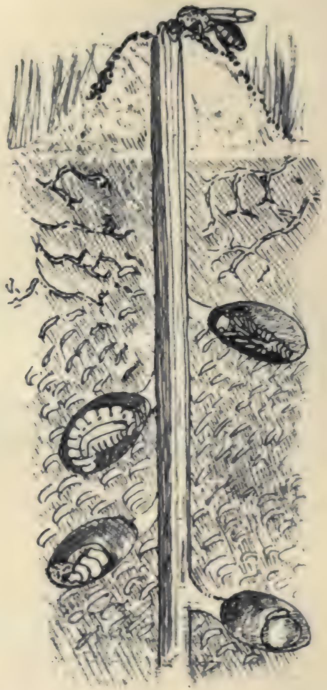

FIG. 60.—Section of the burrow of *Andrena*, one of the Solitary Bees. The main-shaft communicates with the lateral chambers in which from below upwards the stages in development may be seen progressing.—(*From 'Riverside Natural History,' by kind permission of Messrs. Houghton, Mifflin & Co., U.S.A.*)

Evolution of the Hive-bee.—Among these solitary bees we find the first traces of that fraternal spirit which is such a dominant impulse in the social ones. The early

burrowers in sandy gardens, *Halictus* and *Andrena*, form associations, either by several bees using one gallery for entering and leaving their private nests; or by tunnelling close together and issuing in anger at the disturbance of an intruder whose presence a solitary bee would overlook; or, again, by hibernating in a little buried cluster, perhaps for the sake of warmth. But whatever advantage is thus gained is but small. The female bee is maid-of-all-work; she is still queen and worker; she lives only for a few weeks of spring, and dies before her young are fledged. Her architectural instinct is as yet rudimentary. The rude cells in which she lays her young are lined with leaves or thistle-down, or stored in an empty snail-shell, over which she piles a vast mass of débris.

The first indications of comb-construction are found in the nest of the four-banded *Halictus*. This little bee sinks a shaft into the earth, and at one side enlarges the burrow so as to form a vault. In this vault it constructs a row of from twelve to twenty-four clay cells, arranged in tiers and only loosely attached to the walls of the vault. The advantage of this arrangement is that air can circulate more freely around the cells, and drainage moisture from the ground does not flow so directly on to them, a protection from mould that is enhanced by a prolongation of the shaft below the level of the vault. In spite of this improvement however, 'rot' kills many of the larvæ.

Origin of workers.—If the efforts of these four- and six-banded *Halictus* to combat their most deadly foe—mouldiness—are not altogether successful, they have succeeded in another direction. The mother lives to see her children emerge, and in exceptionally favourable localities receives help from them in protecting and extending the colony.

The first to hatch sometimes stay, one to guard the entrance of the shaft, others to quest for honey and pollen, or to build and stock more cells. Thus we have queen and workers for the first time ; but these workers are potential queens, and only in the richest districts do they remain to form a temporary colony. They in turn lay eggs, and from these drones arise in the late autumn. One of the workers mates with a drone, becomes a queen and hibernates in the deserted nest until the next spring.

The casual association of the first-born *Halictus* with their mother and home becomes a settled habit in the case of bumble-bees. The yellow and red-tipped varieties still build underground. The first warm spring day wakes the isolated queens that have survived the winter. From their retirement they take a first flight in search of summer quarters. Each queen works by herself. The common *Bombus* sinks a shaft which she expands to form a cavern. Hither she brings wood, moss, and leaves, then goes out again and fetches some honey and pollen, and now her behaviour differs in a marked way from that of the solitary bees. Unlike them she has the advantage of possessing wax-plates

on her tail, and her first step, under cover of the moss, is to surround with wax a mass of pollen saturated with honey, construct a cell, in which she lays several

FIG. 61.—Nest of Bumble-bee showing the barrel-shaped cells hidden underground in a hollow which leads to the surface by a curved shaft. —(*After J. G. Wood. From Wood's 'Strange Dwellings.' By permission of Messrs. Longmans, Green & Co.*)

eggs, then closes it and rests awhile. A few more cells are then built, stored with honey mixed with pollen, and closed. By this time, however, the first larvæ have hatched, and only being provided with

little food they soon require further supplies. To meet this demand the queen adopts a new method; she opens the cells, discharges from her mouth a little nourishment into them, and then closes up the openings. A little later when the larvæ are pupating, the queen adds to her labours by scraping away the waxen wall of the cocoon, and thus helps the first batch to hatch out. This batch is composed of bees similar in most respects to the queen, except in point of their smaller size. They are, in fact, fertile workers, and take part in the extension and nutrition of the colony. Lightened of her garnering labours, the queen leaves the nest but little, and devotes herself almost entirely to the task of laying as the workers produce fresh cells of wax and pollen. Thus, as the summer advances, the bumble-bee's nest, in a bank or under a stone-heap, is composed of active workers (the race most familiar to us) and the queen mother, who rarely leaves the nest.

In the height of summer, however, a change ensues. By this time the nest presents an irregular appearance. The old cells are never used again as brood-cells, but simply form the foundation for new ones, and are at most stored with pollen and honey, and altered in size and shape to make honey tubs. Moreover, the brood-cells are not of a uniform size. The majority, those that have furnished workers, are the smallest, but they are all empty; a few exceptionally large are to produce queens, and between the two extremes are a few of intermediate size, in

which drones will be born. Between the queen and drone cells and the worker cells there is thus this curious difference, that neither of the former contain any honey or pollen. The eggs are laid in empty cells, and the larvæ are fed exclusively on the special nutriment secreted by the workers ; and the workers having laid the drone-eggs and finished their building construction, are now concentrating their attention upon the feeding of the unborn queens and drones. To this, as to their earlier labours, it would seem that they are summoned each morning by a trumpeter, who acts as ' knocker-up ' at three or four o'clock. This almost incredible statement was made over 200 years ago, and apparently, owing to the lack of a similar institution among naturalists, has only recently been thoroughly confirmed. There is, however, now no doubt that each morning a large worker climbs on the roof of the nest about quarter to four, and then for half an hour, or an hour, buzzes loudly while she also continuously flaps her wings.

The performance is not known to be repeated at any other hour, and at first one is inclined to regard the sound as a warning note. However likely this may be, the beating of the wings would seem to indicate that the trumpeter ventilates the nest, and that this is the real object of the performance. If so, the bumble-bees in this, as in many other ways, foreshadow the more complete polity of the hive-bees, many of whose workers take a spell at ventilation exercise during the midday or evening hours.

Towards the end of summer the colony, which at its richest and most prosperous phase contained from 300 to 400 individuals, shrinks to a third of that population. In autumn the drones and workers completely die out, and of the queens, a few hidden in crevices are all that are left of summer's host. Boys, mice, shrews, and a host of parasites ravish the nests, and the moulds complete the work of destruction. The bumble-bees, therefore, have not solved the crucial problem of insect life, namely, how to extend longevity and lessen the ravages of winter. But in the care of their young they have made immense advance over the solitary bees. The conversion of the first brood into workers that systematically remain attached to their birthplace or move together to a new site, is the foundation of the caste system. Wax is made use of for the first time, though carelessly and in a more or less irregular pot-shape. Reservoirs for honey are constructed. Ventilation is improved, and a distinction made between the nutrition of the first-formed workers and of the later drones and queens.

In all these methods the social bumble-bees have improved on the solitary, banded *Halictus*, as did this on the simple *Andrena* and short-lived *Prosopis*; and the line of improvement is for the most part just that which the hive-bee has brought to such a high degree.

In this evolution we have referred more than once to the impetus given by exceptionally good seasons or surroundings, and have pointed out that it was in

connection with such fortunately placed colonies that the critical advances in organisation were probably made. It is, therefore, interesting to observe what result adverse conditions exert on a bee raised to the middle social condition of the *Bombus*-class, and the increased amount of attention to Arctic animals allows us to do this. We now know, thanks to the twenty years' observation of Dr. Schneider, that in some species of Arctic bumble-bees workers do not occur, in others they are very rare. These bees, therefore, have returned to the solitary mode of life, and in order to utilise the short summer they work by the midnight as well as by the midday sun. Conversely it is found that in Corsica there are indications of the favouring influence of the milder winter. For there, even in spring, some of the bumble-bees are males and some females, and the colonies are not so nearly decimated as in our own climate.

How this last enemy, death, has been prevented from devastating bee-colonies is the problem, the solution of which has given the hive-bee its high place and importance above all other bees. We do not know with certainty how this critical improvement was effected, since, in its several forms, the hive-bee is now domesticated or semi-domesticated all the world over, and, as is so frequently the case in the past history of cultivated creatures and plants, we have lost the wild stock, or stock from which it sprang. Nevertheless, some indications remain, and these, as we should expect, are for the most part exhibited by bees

of warm countries, therefore less familiar and less accurately known bees than the cosmopolitan *Apis mellifica* or honey-bee.

The tropical bees, or *Meliponas*, that to some extent bridge over the gap between the bumble-bee and the honey-bee, are amongst the smallest of their kind, and hence are called mosquito-bees. They associate in vast colonies, and build nests in hollow trees, in the soil, in walls, or among branches. The structure of the nest is a considerable advance on that of bumble-bees. The cells are cylindrical, sometimes irregularly, sometimes regularly arranged, oppositely or spirally in tiers, one above the other. The special pots for honey, and jars for pollen, are still more striking than in the bumble-bees ; and in order to guard them a special conical cap of resinous wax or propolis is constructed, open by day but closed at night, and under cover of this cap a guard is steadily maintained. In some of these nests the cells are all alike, in others the royal cells are easily distinguishable ; but by what cunning nutrition the queens are fed we are not as yet aware.

The caste organisation of these colonies is largely that of the honey-bee. There is only one reigning queen to each colony. The workers are now no longer potential queens, as in the bumble-bees, but are devoted exclusively to building, storing, nourishing and ventilating services, whilst the queen has entirely renounced active life and merely fills the prepared cells with eggs. The drones, however, are not such wasteful parasites as those of the honey-bee, but secrete wax

and assist in the construction of cells. Whether these *Meliponas* swarm after the fashion of hive-bees is uncertain, and has not yet been confirmed.

All those characters that make for efficiency and permanence are enhanced in the hive-bee. The colonies are permanent. From each, at the height of its prosperity, a swarm of workers issues which is led by the old queen and forms the nucleus of a new settlement, whilst the workers left in the old colony rear, by a special food, a new queen from one of the royal cells, and she, after the destruction of her royal sisters, assumes the command. The old colony is thus gradually re-established. The structure of the hive is such as to economise space and to accommodate the largest amount of breeding and storage cells. The royal cells are few and somewhat acorn-shaped. The large drone-cells, and those for storing extra honey, are linked up with the great mass of worker and storage cells by a series of transition cells. Each cell is a hexagonal tube, and it has been shown that by adopting this form for their cells the bees have solved with mathematical nicety the problem of how most closely and strongly to fit cells together. But not only have bees combined these advantages with the greatest thrift in material, they have also bound the cells together into a comb, and attached it to the hive-walls in a way that combines symmetry and strength, whilst yet permitting of traffic, incomings and out-goings, and ventilation without mutual interference.

The diverse kinds of cells are evolved from one

another so as to exclude waste of room, and the different castes are not due to any variation in the shape of the cell in which they are reared so much as to the food with which they are supplied. Both workers and queens receive at first a kind of jellied milk (produced either by the salivary glands or by the stomach of the worker nurse, and possibly, when supplied to the queen larvæ is not identical in constitution with that given to the young workers) ; but whilst this diet is continued for the queen, it is cut off from the young worker after a few days, and for the rest of its larval life the worker is given a coarser diet of honey, pollen, and water. The drones usually arise from a somewhat different egg, but it is not certain whether in this sex, too, the larval food may not have some influence, since it is thought that drones receive more royal jelly than do workers.

The Nests of Ants.—In the care of their young, ants show more simplicity and flexibility of instinctive nursing capacity than are exhibited by any other animal. The nest is adapted to the nature of the surroundings, and is sufficiently large to enable the ants to adapt their charges to variations of climate. The eggs, instead of being laid in cells, are deposited loosely in the nest, and are carried, watched, and cleaned by workers. When the colony is prosperous a vast flight of males and females takes place from a large tract of country, under heavy, thundery, hot conditions. From the turf there spring fountains of these winged creatures, and for miles on the same or

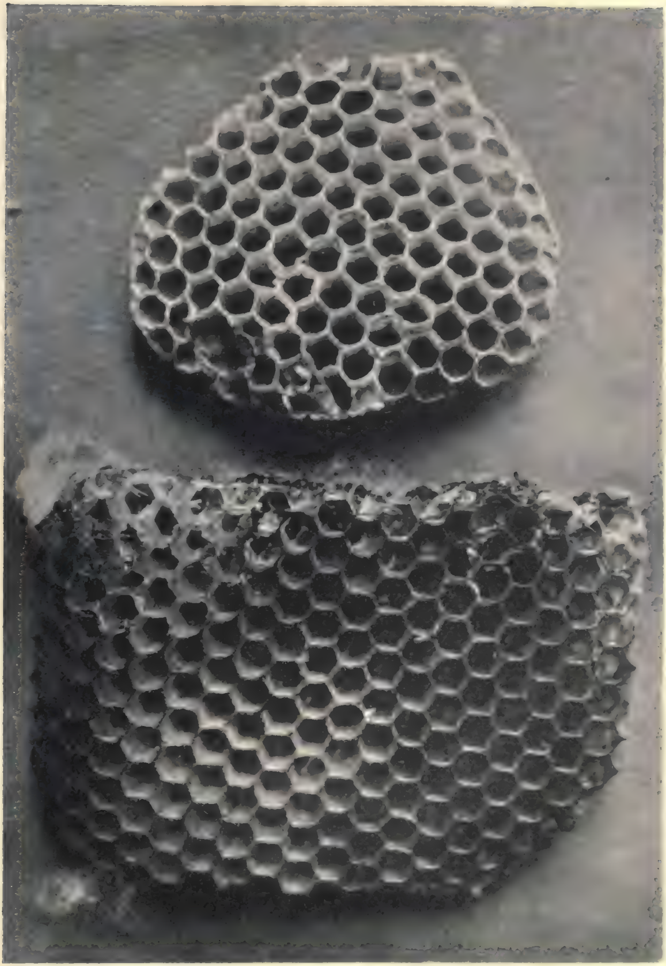

FIG. 62.—Worker-cells from Bee-comb.
(*From a specimen in the Manchester Museum.*)

successive days this wonderful exodus or swarming will proceed. In loose order this cloud will drift over the countryside, harassed in the air by swallows and other birds, and by larger ants on the ground. What the fate of these swarms may be is imperfectly ascertained. The males probably die immediately, but those females that escape the ravages of foes and of accidents are probably either annexed by some wandering workers of the same species or set up new colonies without aid. Some appear to do this at once, and others not until the following spring.

After the swarming of the males and females from each nest the workers are left with a small store of pupæ, and it is probable that from these the new queens are developed, somewhat as in hives after the departure of a swarm with the old queen. But among ants, as several queens are allowed to reign simultaneously, there is no combat between the first new queen and her rivals. Moreover, in some cases a queen will remain for many years in the same nest, active to the last. The best established instance of this longevity was that of a queen kept by Lord Avebury, which lived to be fifteen years old. That is as long as a dog, and three times as long as the oldest known bee queen.

The long life of the queen would not, however, prove that the colony persisted. The workers of a beehive rarely survive more than one summer, but the colony survives the winter by replacement of moribund by new workers, by the elaborate and largely artificial

precautions adopted by bee-keepers for retaining sufficient heat. All other communities of bees and wasps are in temperate climates destroyed each winter and built up anew each spring and summer. Of our native insects only the ant is able to survive the winter, both as an isolated queen and as a colony of queens and workers. This power of survival is rendered possible by the longevity of the workers, which, in some cases, extends for five years ; but it is determined far more by the precautions taken by ants to evade the deadly influences of autumn and winter. They retire to the deepest layers of their nest, sometimes to a depth of nine feet, and so escape the effect of frost. Ultimately, however, the persistence of the colony can only be explained by attributing to ants a power of resistance to adverse circumstances which other insects, with few exceptions, do not possess. However that toughness may be explained, its influence on the dominance of ant-life has probably been decisive, for the resurrection and resumption of work by the old colonies, supplemented by the growth of new ones from the isolated autumnal queens, enables the work of the previous year to be continued and extended. The longevity of workers gives them an opportunity of improving by practice those instinctive traits which they first exhibit when young ; and since the workers for good or ill control the growth of the colony, most of its distinctive features must be attributed to them.

Amongst the various offices they perform the

most important is the care of the young. In a new colony begun by a solitary queen no workers are present. This queen forms a small burrow, lays some eggs, and when these hatch she feeds, cleans, and tends the larvæ and pupæ. These emerge as workers of different sizes, and they at once relieve the queen of most duties. They extend the colony, make roads, hew wood, draw water, and, above all, tend the young, not only cleansing them of every speck and germ, taking them upstairs for warmth and downstairs for safety, but supplying with their own lips and conveying to those of the larvæ all the nourishment that the young require. The quality of this nourishment is probably the decisive factor in the sex and character of the offspring. By increasing the amount of fatty saliva, comparable to the royal jelly of bee-workers, which the nurse supplies, she can produce a queen instead of a worker, and probably some slighter difference in the quality or quantity of the food she affords, decides the size and character of the worker. Possibly the nurse determines certain features of the short-lived male brood, for as in bee-drones so among ants it is probable that the males arise from eggs different in composition from those which produce workers, soldiers, or queens. This passion for nursing has led to very curious results, for the workers in many colonies are, as it were, not satisfied to rear only their own kind, but extend their brooding care to the young of other insects, even to the detriment of their proper charges. The influence of this fostering

habit has been discovered quite recently, but since it throws an unexpected light on the origin of the intermediate castes that link worker and queen or fertile and infertile workers together, and further suggests how the relative numbers of these annectant forms may be explained, we may refer shortly to this aberrant habit.

In most colonies of an ant (*Formica sanguinea*), somewhat rare in this country, the extraordinary spectacle may be seen of one or more foreign ant species acting as slave-nurses more efficiently than the indigenous workers with whom they either share the household work or assume the nursing entirely. Besides these slave-tenanted colonies there are some in which a little cock-tail beetle has taken up its abode. This visitant is not accidentally present, but is deliberately reared by *sanguinea*-ants, apparently for the sake of an ethereal drink which distils from little yellow tufts placed on different points of its body. This dram is solicited by the workers applying their antennæ to the cock-tail's body, stroking it, and lapping the liqueur with their tongue. The beetle-larvæ are, however, not content to be merely fed by the ant-workers, but ravage the colony, eating up eggs and young, so that not only does the state become impoverished and the nurses dissipated, but the young ants receive insufficient nourishment to convert them either into workers or queens, and become stunted and unable to build, nurse, defend, or extend the colony. Fortunately, however, the

ants foster the beetle-larvæ also, and, as they nurse these adopted children as their own, they inflict upon them a treatment which is utterly unsuited to their needs, though appropriate to those of ant-larvæ. During the early larval stage all goes well; the young beetles, fed by the ants and feeding on the ant-eggs and young, grow rapidly, but when they are about to reach the pupal stage the ants bury them, then unearth them, carry them to the surface and again bury them. This treatment, suitable for ant-pupæ, is the death of the beetle-larvæ, and the mortality is more than 98 per cent. This result is the salvation of the colony, which would be decimated were the beetle to increase at the rate their foster-nurses strive to attain. For it is just those nests most infested by the beetle which produce most stunted ants, and the perverted nursing instinct of *Formica sanguinea* works out the salvation of its race (Wasmann).

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